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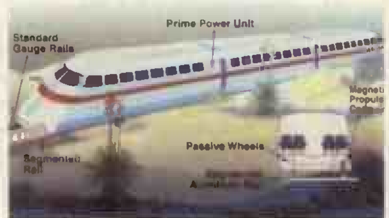
CONTENTS

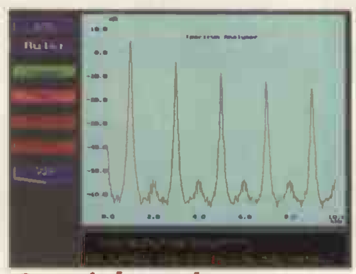
REGULARS

An electro-acoustic measurement system for £750 – representing a 20% discount exclusively for EW+WW readers. Turn to page 780.

Cover – Hashim Akib



Development of a high-speed, magnetically powered train that does not levitate, is inexpensive, and can run on already-laid track – page 721.



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Eight motorway tolling systems are about to be tested, starting next summer on a stretch of the M3, page 716.

Next month: **Probe for measuring mosfet switching losses, Triple stepper motor controller, Very fast power amplifier for instrumentation, Hybrid valve amp, Analysis circuits from energy use.**

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REED BUSINESS PUBLISHING

The industry we never had

During the industrial revolution members of the aristocracy wishing to spend an inheritance building a steam powered car or a flying machine could always find an artisan to assist them. Around this relationship, Britain's industries prospered and a number of Lord & Blacksmith Ltds became world leaders.

In the early nineteen eighties it seemed history might repeat itself. University professors scoured the countryside looking for someone to turn their designs – half of which were never committed to paper – into working instruments.

We were on our way – a few winners; personal computers, digital effects consoles – the new industrial age.

But earlier this year one of the last major subcontractors – Race – limped off the pitch.

What went wrong? It wasn't, as some suggest, that we let the industry slide Eastwards. More the case there was no real industry in the first place.

Prise open the casing of modern consumer electronics products. For all their functionality, you'll usually find a chip count of one at the most. Why aren't British engineers assembling these products? Because no-one is assembling them. There's someone standing next to the machine which makes them, but the skill needed for this is minimal. In the production of a single chip device the most complicated operation is getting Parcel Force to deliver the components.

Who are the losers? For one, any electronic assembly company which was going for growth in the late eighties. Then there's the component supplier who expanded out of a shop between the shoe repairer and the gent's hairdressers to end its life as a 'For Sale' sign stuck on a warehouse next to a motorway intersection. And of course there's the financier who gave a whole new meaning to the term solder sucker.

The part of the industry which remains is the low-volume, high-quality sector. The bulk of the low value work travels around the world like a Mexican Wave. It seemed it would settle next to the chip manufactures in Japan or Taiwan but its on the move again. China, Africa who knows where labour will be cheap next year. The functionality of the chip will increase, perhaps to the level of serial input and output, with a massive number of uncommitted gates in between. The minimal skill needed to glue this to power rails on a pcb can be found anywhere – to do it in Britain is a waste of a resource.

Although Britain did hang on too long, today's view of the world is more realistic. It's no longer just the university Professor who wants a circuit built, but Siemens who need chips designed. If all the action is in the chip itself then is this such a bad thing? It takes the skill of an artisan to prototype a pcb and, as the rest of the world is telling us, these skills are also needed to develop integrated circuits.

Peter Kruger,
flames@flames.cityscape.co.uk

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Decision on road toll trials

Eight motorway tolling systems are about to be tested, starting next summer on a stretch of the M3.

The Government has finally made a decision to go ahead with trialling the electronic toll collection systems with eight of the original 29 bidding consortia.

The chosen consortia are ANT Bosch, Autolink UK, EuroPassage, GEC-Marconi, Tollstar and Tollway proposing microwave-based systems; EasyToll with a system based on global positioning satellite navigation; and Siemens Traffic Controls developing an infra-red two-way communication system.

The consortia will initially carry out trials next summer at the Transport Research Laboratory in Berkshire, followed by tests on a section of the M3 near Basingstoke.

If any of the systems prove successful they may be installed on UK motorways in the next century.

Although the basic in-vehicle unit may cost around £50, more expensive units will be available which will provide information such as route guidance, weather and congestion details.

Computers look back

Researchers have developed a computer system for recognising facial expressions. Even tiny movements in seemingly unexpressive faces are recognisable.

A team at Tokyo University has built a prototype computer-based system for analysing facial expressions to determine human feelings like joy, anger and sorrow.

The position of 21 reference points, like nose tip and eyebrow top, are located on the analysed image of the face. These are used to fit the image onto a digital wire-frame face model to 'normalise' the face.

Once done the relative movement of 48 points, some coincident with the original 21, is analysed.

The analytical software is sophisticated enough to tell the difference between people with un-expressive and over-expressive demeanours and apply a second level of normalisation to account for this.

The current system can identify several basic feelings including happiness, anger, sorrow, surprise and fear. Even the tiny movements in seemingly unexpressive faces are discernable.

A second part of the experiment reconstructs and displays the original facial structure from the emotion information and both sets of normalisation parameters.

Away from conceivable 'big brother' applications, the research could provide the basis of extreme data compression for videophones or allow future computers to communicate with people in a manner closer to normal human interaction.

Circuit board shortage affects UK users

A world shortage of printed-circuit board laminate is putting US firms out of business and is threatening UK producers already struggling with severe allocations.

Circuit board makers are being told that a system of rationing is being considered by the laminators because of the shortage of woven glass yarn.

David Heywood, technical manager with the German laminate company ISOLA Werke, advises board makers to "plan their usage and keep their laminate suppliers informed".

Heywood added: "The problem is world scarcity of the spun glass yarn from which FR4 laminate board is made. European manufacturers of yarn have not been investing in looms that make it.

The situation is exacerbated by the decline in the pound against other major European currencies.

Brian Haken, director of the UK pcb trade association, PCIF, said: "pcb makers face a difficulty in passing on laminate price rises to OEMs, and OEMs for their part, expect year-on-year unit cost reductions."

New technique reduces rf chip count

US firm TRW has developed a chip fabrication process that could reduce the number of rf chips in mobile phones and other wireless equipment.

The technology allows, for the first time, the fabrication of both high electron mobility transistors – hemts – and heterojunction bipolar transistors – hbts – on the same substrate.

The technology is currently being employed in a satellite programme, but could be offered to other equipment makers. Dwight Streit, a spokesman for TRW, said: "There has been no decision yet to sell combined technology chips to other OEMs but it would give us a tremendous advantage when bidding for new business."

Hemts are the output devices in many rf power amplifiers, but are too noisy for receiver input stages where hbts are favoured. Hbts are, in turn, not linear enough for optimised output stages.

But putting both hemts and hbts on the same chip means the hbts, which are relatively fragile, are normally damaged by the thermal cycling required to fabricate hemts.

TRW's solution has been in two parts; first it has progressively developed more robust hbt materials and second, it has designed a process that protects the hbts while hemts are grown.

The resultant devices have the same characteristics as separately grown transistors.

A spin-off is that the control circuits required by hemts can be made with on-chip hbts rather than off-chip silicon.

In the process, the hbt layers are epitaxially grown and then selectively etched to form the hbt transistors. A silicon nitride protective film is then laid down.

The hemt layers are then grown. Selective etching then removes the unwanted hemt material. So far, the process has proved successful with GaAs and InP substrates.

***Steve Bush,** Electronics Weekly*

Motorola joins display technology alliance

Motorola is to develop flat panel displays based on field emission technology – FED – and has joined the PixTech alliance of companies developing screens based on the technology.

Motorola and the other members of PixTech, which includes Texas Instruments, Raytheon and Futaba, are betting that the FED based screens will result in cheaper and better quality colour flat panel displays.

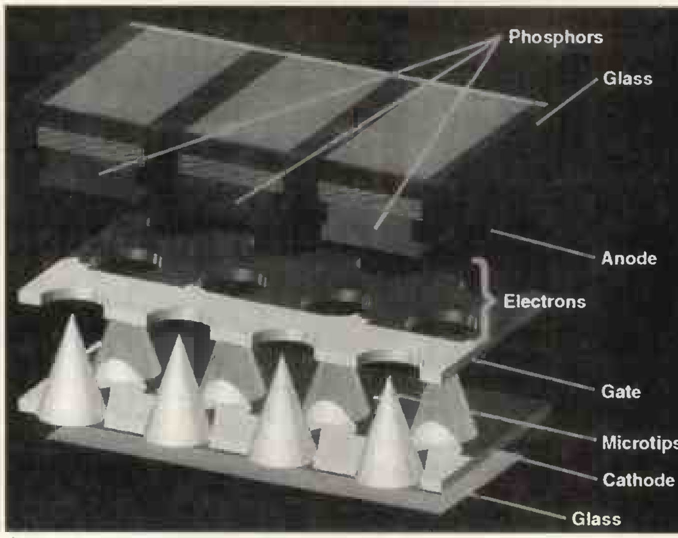
"We're working on the technology for next generation displays," said Pete Shinyeda, Motorola vice president and general manager of Motorola's Flat Panel Display Division. "This technology will make it possible to manufacture displays that are bigger yet lighter and thinner, brighter yet more efficient, and are capable of full motion and colour."

Shinyeda predicts that FED based displays will find a wide range of applications in portable computers, cellular phones and video games systems.

FED displays offer many of the same benefits of cathode ray tube displays but are thinner, lighter and use less power.

Instead of a single cathode ray source, FED relies on hundreds of cathode ray sources for each pixel. Such displays should be easier to manufacture than active matrix liquid crystal displays which suffer from relatively poor production yields because of their complexity.

Field-emission displays offer many of the benefits of cathode ray tube displays but are thinner, lighter and use less power.



Three US companies battle for unified memory first

Three US firms are working towards being the first to market with pc core logic chipsets which support the proposed unified memory architecture, reducing the amount of dynamic ram required in pcs.

Next month pc chipset specialist OPTi will announce a two-chip design which the company claims will remove the need for 32Mbyte of frame buffer d-ram in Pentium pcs resulting in a $60 cost saving.

By the end of the year, graphics specialist Weitek will be sampling its first single chip memory controller and graphics accelerators, *W464* and *W564*, which will support unified memory designs in 486 and Pentium-class PCs.

VLSI Technology, one of the leading Pentium chipset suppliers, is expected to introduce its single chip unified memory design, called Coyote, at the turn of the year.

The use of the one block of d-ram for cpu main memory and graphics frame buffer has been made possible by the availability of new forms of high speed synchronous d-ram. As well,as saving on a quarter of the memory in a pc with 8Mbyte of ram, chip suppliers are convinced the new designs have implications on the future development of the pc architecture.

OPTi's two-chip design which is being evaluated by the VESA standards body, is seen as a lower cost implementation which will be incorporated into pcs next year.

OPTi is working with market leading graphics accelerator suppliers S3, Trident and Cirrus logic, to ensure compatibility. "The approach has the potential to be a *defacto* standard because of the collaborative effort with the graphics vendors," said Prem Talreja, director of marketing for core logic at OPTi, but he admitted there could be a ten percent performance penalty largely due to bus arbitration.

According to Chas Rimpo, at VLSI Technology, the Coyote one chip design, will create no penalty and could enhance performance by running graphics on the 66MHz system bus.

***Richard Wilson,** Electronics Weekly*

One-chip fuzzy controller is low-cost

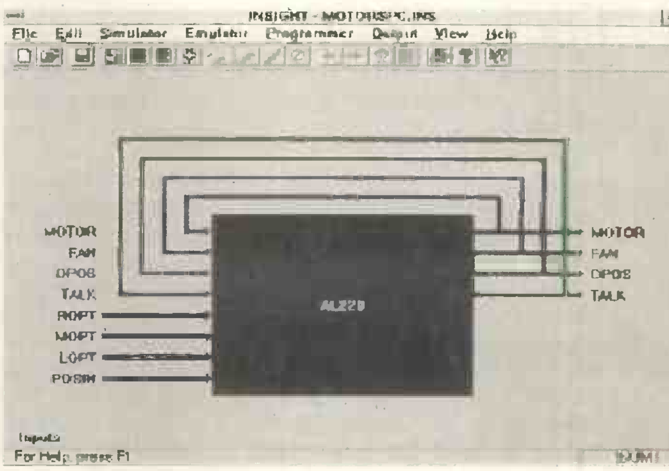
A reconfigurable microcontroller that executes fuzzy logic control in hardware has been developed by Silicon Valley-based Adaptive Logic. The device, the *AL220*, is a low cost single chip fuzzy logic processor targeted at the large eight-bit microcontroller market.

In addition to a processing core, the device features on-chip a-to-d and d-to-a converters.

The core performs fuzzy-based control on up to four analogue inputs. It first fuzzifies the input data, processes it based on the chosen rule set – the rules which capture the actions to be performed for given input conditions – before defuzzifying the data to generate output values.

The accompanying Windows-based development tool, called *Insight IIe*, enables a designer to capture and simulate the fuzzy design. An emulator is also provided, allowing the control algorithm to be linked to the application and be executed in real time. On design completion, the fuzzy rules are programmed into the *AL220*'s on-chip 256×8 eeprom, much in the way a logic array device is programmed.

The store can hold about 50 rules, with a processing performance of 500,000 rules per second. According to: Adaptive Logic's president, George Schneer, implementing the algorithm in hardware avoids having to write and debug software using a standard microcontroller. "This reduces development cost and time to market," said Schneer.



In addition to a fuzzy processing core, the new controller has on-chip a-to-d and d-to-a conversion.

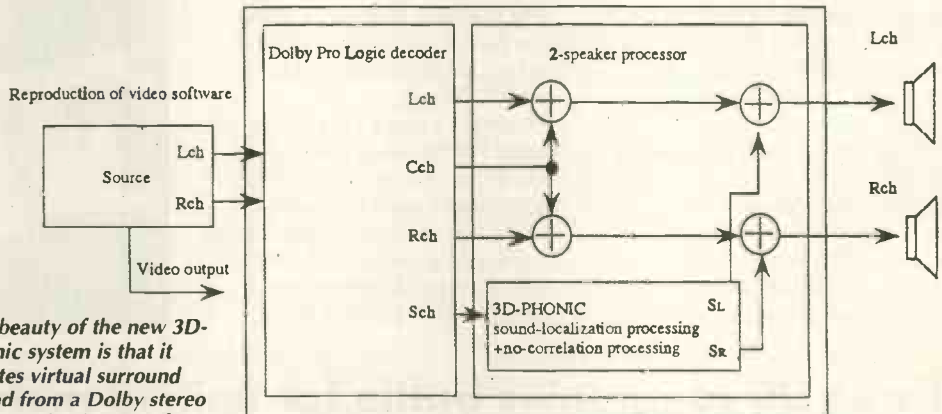
New surround sound system

JVC has developed a virtual surround sound system called 'Dolby Pro-Logic 3D-Phonic' that creates a surround effect from a Dolby Stereo source using just two front speakers.

The Dolby Pro-Logic Surround decoder and 3D-Phonic processor have been programmed into a single lsi chip. And the first product to use it is a 29in tv retailing at £900 – with other home audio-visual products to follow.

The centre-channel signal is added in equal amounts to the left and right front channels to maintain its central sound image. Because the surround channel signal is mono it requires processing before being added to the left and right channels. Otherwise, it too would seem to come from the centre. This is prevented by reducing the correlation between the signal going to the left channel and that to the right, together with a degree of phase shifting and retiming between them. The result is the apparent localisation of the surround channel in symmetrical positions on either side of the listener.

Normal stereo and mono are reproduced without processing. While direct audio line outputs from the Pro Logic decoder are included for those who prefer separate front, centre and rear speakers.



The beauty of the new 3D-Phonic system is that it creates virtual surround sound from a Dolby stereo source using just two front speakers.

Gas sensor breakthrough achieves ten times more sensitivity

Tokyo based Nippon Telegraph and Telephone, NTT, claims to have developed an electronic smell sensor that can detect gas concentrations of a few hundred parts per billion – ten times the sensitivity of conventional sensors.

The sensor consists of an array of eight quartz crystals, each coated with a different organic gas absorption film.

The resonant frequency of each crystal is affected by gas absorption and is monitored over time. The array is sensitive to a variety of smells and a pc performs pattern recognition to differentiate between burning smells and others.

The sensing technique can be extended to detect virtually any gas or odour.

Semiconductor orders up 38%

The computer sector was the main factor in creating demand to exceed supply for semiconductor products for the UK and Eire, reported the Semiconductor Manufacturers' Association (SMA).

This has allowed companies to fill their order books, although there are capacity limitations.

For the year to date, the order intake was 38% higher than last year's, while for billings it was 28% higher.■

RESEARCH NOTES

Jonathan Campbell

Differential gps brings top honours for flying robot

Students have used a gps technique that can give a positional accuracy of centimetres rather than the usual 10m to win an award for their design of a flying robot. In the Annual Aerial Robotics Competition held in Atlanta at the Georgia Institute of Technology, a team from Stanford University's Aerospace Robotics Laboratory used gps for accurate determination of the position of its flying robot, allowing the robot to navigate a course and carry out some predetermined tasks.

The competition, sponsored by the Association for Unmanned Vehicle Systems (AUVS), requires that flying robots locate six small metal disks scattered in a 2m ring, capture them one at a time, carry each of the disks over a tennis net and drop them into a second 2m ring – all without direct human control.

Stanford's autonomous flying machine was the first entry to use satellite navigation to control movement, with an on-board computer relying on gps to update its position, including altitude, five times per second.

The military gps system was originally designed to limit the accuracy available to civilian users, but the students used a technique called differential carrier phase gps to provide the computer with position information accurate enough to follow a pre-programmed course.

Their robot helicopter sported four gps antennas, two gps receivers and a 486 computer to control the helicopter's orientation as well as its motion. Precise positions of the boundaries of the competition area, and the location of the starting point, pick-up ring, net and drop-off ring were first determined by the students. Then the on-board computer was programmed to instruct the helicopter to climb to a set altitude; calculate the direction to the pick-up ring; fly to the pick-up ring; drop to the correct altitude so that the pick-up magnets would just drag on the ground; stay in the pick-up area for a few seconds; climb to an altitude high enough so that the magnets would clear the net; calculate the direction to the drop-off ring; and fly to the drop-off ring.

The autonomous flying machine became the first entry not only to hover under control, but also to move to the ring containing the metal disks and pick one up.

Differential carrier-phase gps helped Stephen Morris, Bruce Woodley and Andrew Conway from Stanford University position their robot within centimetres rather than metres.

On its maiden flight, the Stanford helicopter disqualified itself by picking up two disks, rather than one. On its second effort, it failed to pick up any disks. But on its third try, it successfully picked up a single disk and carried it over the net to the drop-off ring.

However, the first prize for designing an aerial robot that can pick up all six disks and drop them in the ring still remains to be won. so there's still time for a UK team to take the honours next year.

High speed magnetic trains are back on the rails

Development of a high-speed, magnetically powered train that does not levitate, is relatively inexpensive to build, and can run on already-laid track could revitalise practical application of magnetic drive technology.

The concept for the train, developed at Sandia National Laboratories, is a spin-off from technology created at Sandia in the late 1980s for the Star Wars programme.

To move the train, pulsed magnets – 30 per 'locomotive'– induce reversed electric currents in a series of aluminum plates bolted to or near the track. The induced currents create their own magnetic fields that oppose those of the train. With the aid of optical sensors, the fields pulse on just as the magnets pass the midpoint of the aluminum plates, and by repulsion propel the train forward. Plates would be pre-assembled in ladder-like sections – the plates serving as rungs – for fast, cheap bolting to the track. The design is also the basis for the name of the train Seraphim: segmented rail phased induction motor.

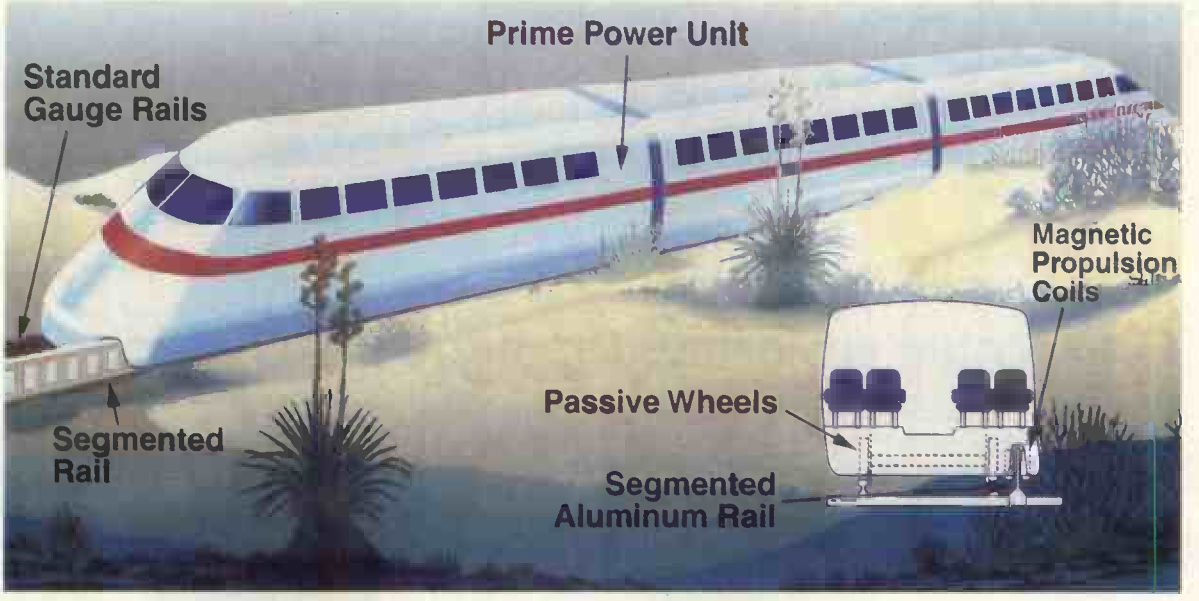
Rather than travel suspended by magnetic fields, Seraphim would ride on unpowered wheels made of steel or composite materials, reducing the cost and complexity of the system.

So unlike mag-lev trains under construction in Germany and Japan, the Sandia approach needs no specially designed track, and permits old-style and new-style trains to travel on the same rails.

Also unlike mag-lev trains, which travel with no engine aboard, the proposed Sandia train would carry its own drive mechanism – a gas turbine that powers on-board electromagnets.

So far, using magnetic coils, a working model has propelled a vertical, two-foot tall aluminum plate along a rail. In less than 4m the plate can reach a speed of 54km/h, demonstrating the potential of the propulsive technique.

The researchers are currently applying for funding to power an actual train to travel at 320km/h. Sandia says the train could achieve



Using available track, Seraphim is powered forward by inducing reversed electric currents in a series of aluminum plates

420km/h, but not on track already laid.

Slow-moving shuttles have used a similar method to achieve speeds of 50km/h. But these trains embed magnetic fields relatively slowly in a neighbouring metal rail to generate a backward-moving wave of magnetic flux which thrusts the train forward. The Sandia method induces magnetic fields around the edges of a segmented aluminum rail placed along the rack, a difference that allows a Seraphim-type train to achieve much higher speeds.

Similarly, experiments with conventional linear induction motors have reached speeds of more than 320km/h, but efficiency suffers at higher speed, while the performance and efficiency of the Sandia engine actually improves with velocity.

Camera wired up to the world

Any *EW + WW* reader currently planning a romantic trip with a co-traveller who is not their partner – if you get my drift – should avoid Boston, Massachusetts. Or if they should find themselves in Boston, they should avoid Steve Mann.

Fortunately Mr Mann is relatively easy to pick out amongst Bostonians going about their normal business: he will probably have a box of electronics and camera lenses strapped to his head (see pictures).

But if he does see you, then you should be prepared to share your secret – with about 20-odd million others. Because Steve Mann and his camera are attached to the Internet, and anyone browsing the Internet can see what he sees.

Mann's system is much more than a simple head-mounted camera.

Instead, visual information from the camera is sent directly to one or more remote processors, with a processed version of the visual information then received back at the head-mounted display, as part of a 'visual filter'.

Mann himself is part of the VisMod vision and modelling group in the Media Lab at MIT, and the purpose of the exercise is to stimulate discussion of everything from visual perception and learning, augmented memory and personal safety/security, through to video postcards – with personal privacy considerations included along the way.

Using the camera system with radio communications, Mann's 'NetCam' can send his visual field anywhere in the world, using the Internet as a communications medium.

So if you want to find out more about how to view Steve Mann's world on the Internet – or want to find where he is so you aren't – contact him at steve@media.mit.edu.

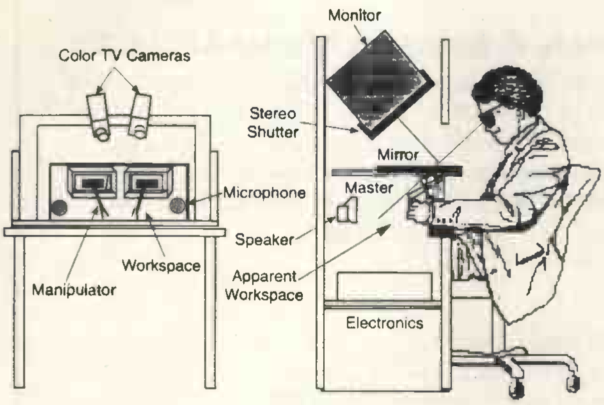
Steve Mann's NetCam has moved on from just attaching a camera to the head and recording what the head movements point at, leftmost photo. Now what Steve sees is transmitted and processed remotely. As a result Internet browsers can view the world exactly from his perspective.

Battlefield operation – and not a surgeon in sight

If the makers of MASH – the television series that memorably recorded life for a mobile army surgical hospital under fire in the Vietnam war – were to try portray battlefield medicine as it is developing today, things could look a little different. Because one of the key components of combat zone surgery could soon be gone forever: the surgeon.

That's not to say the soldiers will

The remote scalpel appears to emerge from the hand controls as the surgeon looks down into the virtual workspace.



no longer be put under the surgeon's knife, simply that the surgeon may be holding it from several miles away through the technique of telepresence.

Remote manipulation has been around for many years, in the handling of dangerous materials for example, though the interface has not been natural enough to allow a surgeon to work.

But now tests being carried out by SRI International in California (Telepresence Surgery, *IEEE Engineering in Medicine and Biology*, PS Green et al, pp.324-329), are showing that remote surgery is a real possibility. Most recently an operation has been carried out by a surgeon 160m away from the 'patient' – a dummy with a pig's intestines.

The SRI system integrates vision, hearing and manipulation using a surgeon's console and a remote surgical unit.

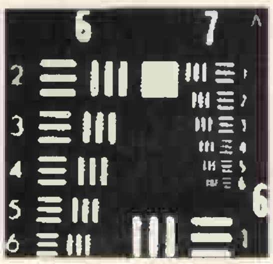
At the console, the surgeon can look down into a virtual workspace recreated by a 120field/s stereographic video monitor with an lcd shutter – the surgeon wears polarised glasses.

In a remote unit, the patient is viewed by a pair of video cameras and operated on by instruments held by a manipulator. The surgeon sees the instruments as emerging from handles he or she manipulates, and is able to sense the resistance of tissues as they are touched by the instruments and feel the suture as a knot is tied. Sounds are also picked up by stereo mics and relayed to the surgeon through speakers to add to the experience.

So far a telepresence surgery system has been installed in a mobile surgical vehicle with the intention that eventually, wounded soldiers will be placed on its operating table to be operated on remotely, improving immediate trauma care under combat conditions.

Field tests are expected shortly.

No image problem for lcds



Photochromic properties of liquid crystals composed of photosensitive azobenzenes could enable them to be used as an optical data storage medium.

Photochromic molecules change their molecular shape upon photoradiation – a property that allows light to be used to control the orientation of liquid crystals. Now Tomiki Ikeda and Osamu Tsutsumi at the Research Development Corporation of Japan have developed a liquid crystal system that demonstrates optical switching capabilities significantly faster than any previous liquid crystal. Thermal stability of the system also means it could hold promise as a storage medium for optical images.

Ikeda and Tsutsumi concentrated their investigations on azobenzenes ("Optical switching and image storage by means of azobenzene liquid crystal films, *Science*, Vol 268, pp.1873-1875).

The attraction of azobenzene is that the trans form of some of its derivatives is rod-like, stabilising the liquid phase, whereas the cis form is bent and destabilises the liquid crystal phase when present. So trans-cis photoisomerisation of azobenzenes in the liquid crystal phase can cause disorganisation of the phase structure.

To carry out their study, very thin films of photochromic liquid crystals (200nm) composed of photosensitive azobenzenes were produced and their photochemical response investigated.

What the researchers found was that irradiating the films with a laser brought the trans-cis transformation in only 200μs, cutting off light transmission through the crystal two orders of magnitude faster than any system investigated previously.

Similarly, when the film was laser irradiated through a mask, then held at the same temperature in the dark, the resulting image remained unchanged after eight months.

The authors believe the properties of thin crystals of azobenzenes could make them ideal for optical switching and image storage.

X-ray film bites the dust?

Scientist in the US are in the process of developing a prototype electronic x-ray sensor that could be the next step on the path to filmless x-ray examinations for patients. Developers claim their design differs from other digital radiographic devices that have recently come on the market in that it provides a better spatial resolution for a given sensitivity to x rays. So reduced dosages for examinees would result too.

At the core of the process is an electronic readout device being developed by scientists at Lawrence Berkeley Laboratory and Air Techniques, the US' largest supplier of automatic dental film processors. First application for the technology will be in dental radiography, but researchers say the goal is to make larger digital devices suitable for mammography or heart imaging.

The conventional way to x-ray teeth is with a piece of thick film that is moderately sensitive to x rays. To increase efficiency and lower the required dosage of x rays, the film can be sandwiched between sheets of plastic called intensifying screens. Disadvantage of using the screens is that they scatter radiation, resulting in decreased spatial resolution and accuracy.

But soon, in place of dental film, patients will be closing their mouths around electronic sensors and dentist and patient will be able to watch images coming up on a computer screen seconds after the device is inserted into the mouth. The images will be higher resolution than film images and will be conveniently stored or manipulated. Dental patients will also be exposed to as little as one-tenth of the x-ray radiation they typically receive now.

The alternative electronic technology, developed at LBL by physicists Victor Perez-Mendez, John Drewery, and graduate student Tao Jing, relies on a light-emitting material, or scintillator.

Vacuum evaporation is used to deposit a scintillator, caesium iodide, on raised pucks dotting the surface of a patterned piece of high-temperature plastic. In the process of evaporation, the caesium iodide forms columns on the plastic pucks. When x rays hit these columns, the material emits light (scintillation) which is partially collimated, and sideways spreading is minimised.

"The net result is that our x-ray-detecting devices are more efficient and more accurate than the commercial Kodak film combination," says Perez-Mendez. ■

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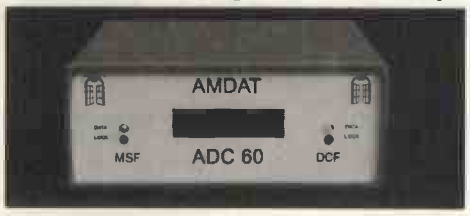

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Designing with a single rail

Analogue expert Walt Jung shows how to design circuits operating from a low-voltage single-rail supply without compromising on performance.

Walt Jung is with Analog Devices Inc.

There is a vast amount of digital circuitry in existence, and much more is emerging. Nearly all of this circuitry operates from a single 5V or 3V rail. Since more and more analogue and digital circuitry is being combined, there has been a rapid rise in the need for analogue circuitry capable of operating from the same low-voltage supply rail as the logic elements.

This collection of applications illustrates low-voltage, low-power design concepts. A variety of stand-alone circuits is presented, each involving single supply and/or low-power circuit design techniques.

Low-power, low-dropout references

There are many problems associated with making stable dc voltage references work from 3-5V supplies. Among these are quiescent power consumption and overall power efficiency, the ability to operate down to 3V, low input/output (dropout) capability, and minimum noise output.

Since supplies of less than 7V cannot support zener mode devices, low-voltage references must of necessity be bandgap types. All circuits shown below work at 5V and up, with many operating down to as low as 3V.[1,2]

One of the more difficult designs is simply to get a reference to work well from very low voltages, say 3V. This dictates use of a reference diode of appreciably lower voltage. One solution is a 1.2V reference diode and appropriate low power support circuitry, **Fig. 1**.

While this circuit appears trivial at first glance, when power drain must be minimised, the options narrow. A low operating current diode is a must for D_1, and here, an industry standard *AD589*. This 1.235V device has a minimum current of 50µA.

Resistor R_1 sets this current, which is chosen for 50µA at the minimum operating supply. In this case, R_1 operates from supplies down to 2.7V. Obviously, loading on the unbuffered diode must be minimised, but generally static loads of a few microamps are fine.

Dynamic loads present a larger problem. Usually, a power conscious designer will not want to burn excess current in a reference diode to cater for occasional load changes. Amplifier IC_1 alleviates this problem, buffering the diode so that higher source/sink currents are allowed, with a quiescent current which follows the IC_1 choice from the table.

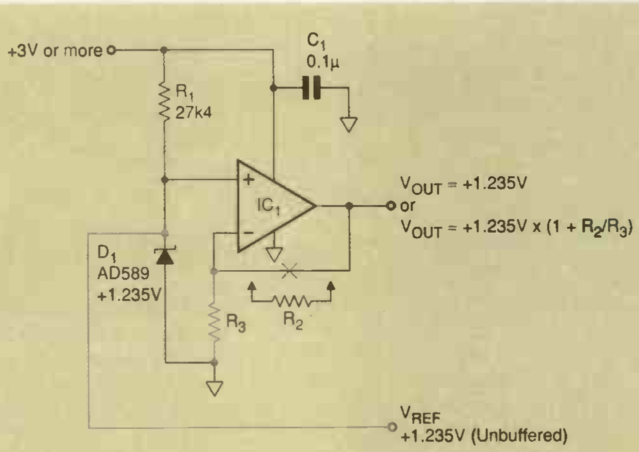
Without gain scaling resistors $R_{2,3}$, output is simply 1.235V; when the resistors are used the output can be set between the reference voltage and the supply rail, assuming a rail-to-rail output swing from IC_1. Amplifier standby current can be optionally reduced to around 20µA if an *OP193* is used, and the listed devices generally operate from supplies down to 3V – except for the 5V minimum *OP279*.

Available output current is set by the device chosen, which can be as high as 45mA, as indicated in the last column. As noted for all rail-to-rail devices, V_{OUT} can approach the positive rail within the levels shown at the specified currents.

Power conservation can be a critical issue with references, just as can output dc precision. For such applications, simple, one package fixed voltage references which simply 'drop in' with minimal external circuitry and deliver high accuracy are very attractive.

Two unique features of the three terminal *REF19x* bandgap reference family are low power consumption and shut-down capability. The series allows fixed outputs from 2.048 to 5V, which can be controlled between on and off via a ttl/c-mos power control input, V_C. It provides a precision reference for the popular voltages as listed in the table of **Fig. 2**.

The *REF19x* family can be used as a basic three-terminal fixed reference as per the table, simply by linking pins 2 and 3 and operating it as shown. It can also be used as an on/off controlled device, by programming pin 3 high or low, as noted.



Typical device specifications for 5V supply and 25°C ambient.

Device	$I_{q/channel}$ mA	$V_{sat(+)}$ V min@mA	$V_{sat(-)}$ V max@mA	I_{sc} mA min
OP193/293/493	0.017	4.20@1	0.280@1 (typ)	±8
OP295/495	0.150(max)	4.50@1	0.110@1	±11
OP191/291/491	0.300	4.80@2.5	0.075@2.5	±8.75
AD820/822	0.620	4.89@2	0.055@2	±15
OP284/484	1.250(max)	4.85@1	0.125@1	±7.5

Fig. 1. Rail-to-rail output stage op-amps help design low drop-out voltage references.

In addition to the shutdown capability, the distinguishing functional features are a low dropout of 0.5V at 10mA, and low current drain for both quiescent and shutdown states, at 45 and 15µA maximum, respectively.

When a *REF195* is used with inputs in the range 6.3 to 15V for example, it can drive 5V loads at up to 30mA. It also has grade dependent tolerances of ±2 to ±5mV, and maximum temperature coefficients of 5 to 25ppm/°C. Other devices in the series provide comparable accuracy specifications, and all have low dropout features.

To maximise dc accuracy in this circuit, the output lead from IC_1 should be connected directly to the load with short heavy traces, to minimise the impact of *IR* drops. The common ground terminal, pin 4, is much less critical due to the lower current in this leg. The 1µF output capacitor is part of the device's frequency compensation, and cannot be omitted.

Regulating with low dropout voltage

By adding a boost transistor to the basic rail-to-rail output low-dropout reference of Fig. 1, output currents of 100mA or more are possible, while still retaining the features of relatively low standby current and low dropout voltage. **Figure 3** shows a low dropout regulator with a 800µA standby current, suitable for a variety of outputs at current levels of 100mA or more.

The 100mA output is achieved with a controlled-gain bipolar power transistor for pass device Tr_1, namely an *MJE170*. Maximum output current control is provided by limiting base drive to Tr_1 with series resistor R_4. This limits the base current to about 2mA, so the maximum H_{FE} of Tr_1 then allows no more than 500mA, limiting the transistor's short circuit dissipation to safe levels.

Overall, the circuit operates as a follower with gain similar to Fig. 1, so V_{OUT} has a similar output expression. The circuit is adapted for different voltages simply by programming feedback resistor R_2 via the table. Dropout with a 100mA load is about 200mV, thus a 5V output is maintained for inputs above 5.2V, see table, and V_{OUT} levels down to 3V are possible.

Step load response of this circuit is quite good, and transient error is only a few millivolts pk-pk for a 30-100mA load change. This is achieved with low effective series resistance switching-type capacitors at input-output, but the circuit also works with conventional electrolytics, albeit with increased transient errors.

If desired, lowest output noise with the *AD820* is reached by including the optional reference noise filter, R_5/C_1. Lower current op-amps can be used for lower standby current, but they may involve a tradeoff of larger transient errors, due to reduced bandwidth.

As noted above, a 'low dropout' regulator is readily implemented with a rail-to-rail output op amps such as those of Fig. 1. This is because their wide output swing makes driving a low saturation voltage pass device simple. Further, it is most useful when the op-amp used also enjoys a rail-rail *input* feature, as this factor allows high-side current sensing for current limiting.

Typical applications are voltages developed from a 3-9V range system sources, or anywhere where low dropout is required to maximise power efficiency. The 4.5V example here works from 5V nominal sources, with worst-case levels down to 4.6V or less.

Figure 4 shows such a regulator using an *OP284* plus a low $R_{ds(on)}$ p-channel mosfet pass device. Low dropout performance is provided by Tr_1, with a rating of 0.11Ω with a gate drive of 2.7V. This relatively low gate drive allows operation on supplies as low as 3V without compromising overall performance.

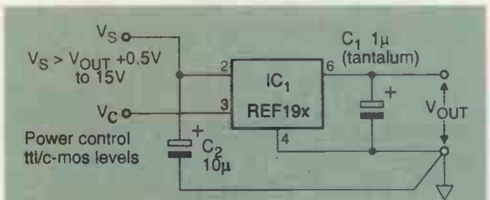
The circuit's main voltage-control loop operation is provided by IC_{1B}, half of the OP284. This voltage control amplifier amplifies the 2.5V reference voltage produced by IC2, a REF192. The regulated output voltage V_{OUT} is then:

$$V_{OUT} = V_{OUT2}\left[1+\frac{R_2}{R_3}\right]$$

where V_{OUT2} is generally the IC_2 voltage.

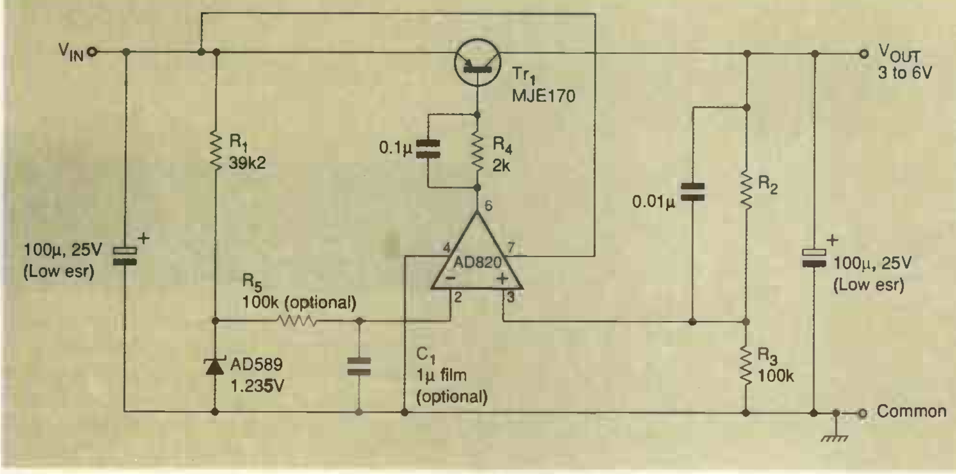
Note that for the lowest V_{OUT} dc error, $R_2 \| R_3$ should be maintained equal to R_1, as here, and the $R_{2,3}$ resistors should be stable, close tolerance metal film types. The table suggests $R_{1\text{-}3}$ values for popular output voltages. In general, V_{OUT} can be anywhere between V_{OUT2} and the 12V maximum rating of Tr_1.

While the low-voltage saturation characteristic of Tr_1 is part of the low drop-out key, the other expedient is a low and accurate current-sense comparison. Here this is provided by current-sense amplifier IC_{1A}, which produces a 20mV reference from 1.235V reference D_2, and the R_7/R_8 divider. When the product of the output current and sense resistor R_{SENSE} match this voltage threshold, current control is activated, and IC_{1A} drives Tr_1's gate positive via



IC_1	V_{OUT} (V)
REF191	2.048
REF192	2.5
REF193	3.0
REF196	3.3
REF198	4.096
REF194	4.5
REF195	5.0

Fig. 2. A voltage reference family with 30mA, low-drop-out features.



V_{OUT}	R_2	V_{IN}(min)
6V	383k	6.2V
5V	301k	5.2V
4V	226k	4.2V
3.3V	169k	3.5V
3.0V	143k	3.2V

Fig. 3. Adding a boost transistor to a low-dropout reference results in a low-dropout regulator providing a 100mA output current, 800µA standby current and 200mV dropout voltage.

D_1. Overall circuit operation is then under current mode control, with a current limit I_{limit} defined as:

$$I_{limit} = \left[\frac{V_{R(D2)}}{R_{SENSE}}\right] \cdot \left[\frac{R_7}{R_7 + R_8}\right]$$

Obviously the comparison voltage should be small, since it becomes a significant portion of the overall dropout voltage. Here the 20mV value used is higher than the typical offset of the *OP284*, but still reasonably low as a percentage of V_{OUT}, at less than 0.5%. For other I_{limit} levels, sense resistor R_{SENSE} should be set along with $R_{7\text{-}8}$ to maintain this threshold voltage between 20 and 50mV.

For a 4.5V output version, measured dc output change for a 225mA load change was of the order of a few microvolts, while the dropout voltage at this same current level was about 30mV. Current limit as shown is 400mA, allowing operation at levels up to 300mA or more. While Tr_1 can support currents of several amperes, a practical current rating takes into account this SO-8 device's 2.5W 25°C dissipation. A short-circuit current of 400mA at an input level of 5V will cause a 2W dissipation in Tr_1, so other input conditions should be considered carefully in terms of the device's potential overheating. If higher powered devices are used for Q1, the circuit will support outputs of tens of amperes as well as the higher V_{OUT} levels noted above.

The circuit can be used either as shown for a standard low dropout regulator, or it can also be used with on/off control by applying a logic control voltage V_C to IC_2. Note that when the output is off in this circuit, it is still active – i.e., not an open circuit. This is because the off state simply reduces the voltage input to R_1, leaving the $IC_{1A/B}$ amplifiers and Tr_1 still active.

When on/off control is used, resistor R_{10} should be used with IC_1, to speed on-off switching, and to allow the output of the circuit to settle to a nominal zero voltage. Components D_3 and R_{11} also aid in speeding up the on-off transition, by providing a dynamic discharge path for C_2. Transition time from off to on is less than 1ms, while the on-to-off transition is longer, but under 10ms.

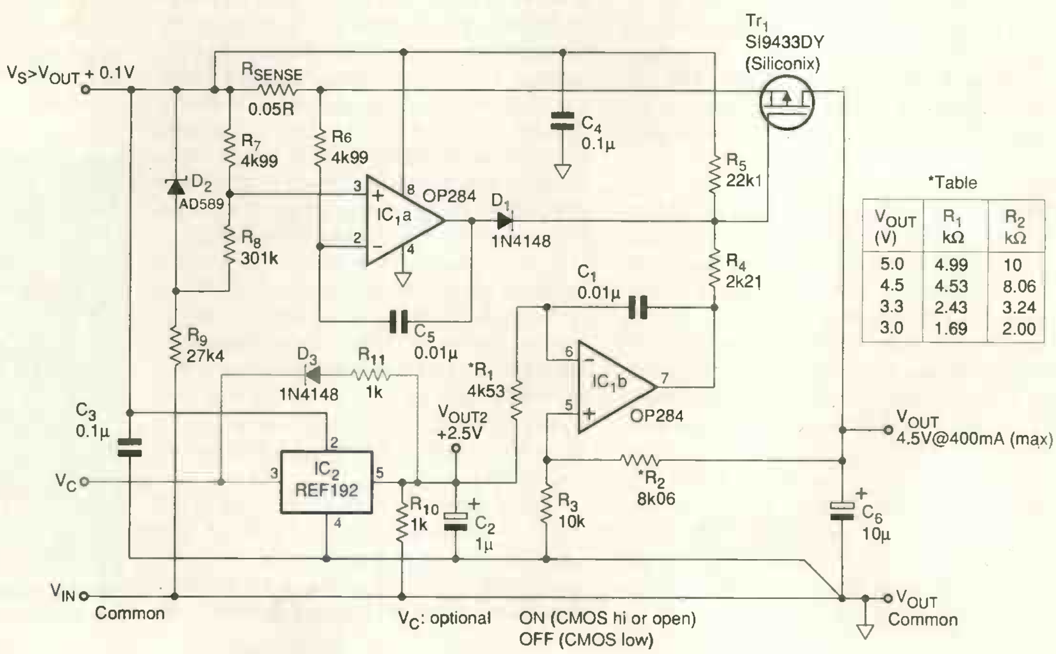
4-20 mA current looping

Amplifier devices with outputs that swing close to the negative rail both enhance and simplify the design of 4-20mA current loop transmitters. A case in point is the circuit of Fig. 5. This is a loop-powered strain-gauge sensor where an amplified 50mV full-scale bridge output is calibrated to drive a 4-20mA transmitter output. This is a loop powered circuit, thus the entire signal processing current budget must stay well below the 4mA offset current level – including bridge drive.

Single-supply instrumentation amplifier, or in-amp, IC_1 is an *AMP04*. It amplifies the bridge signal linearly by a gain *G* of about 40 times, where gain is determined by R_{GAIN}. The *AMP04* output swing includes the negative rail, so the 0-50mV bridge signal is amplified to a nominal 0-2V signal referred to the loop common bus, pin 5 of IC_1. With all device negative supply pins referenced to this bus, the bulk of the loop quiescent current is made to flow into R_6, plus the external loop and the 100Ω termination, R_{LOAD}.

With no output from the bridge, IC_1 output will be at the negative rail. No current then

Fig. 4. Low drop-out voltage regulators are useful for battery applications. This 300mA regulator features high-side current sensing.



*Table

V_{OUT} (V)	R_1 kΩ	R_2 kΩ
5.0	4.99	10
4.5	4.53	8.06
3.3	2.43	3.24
3.0	1.69	2.00

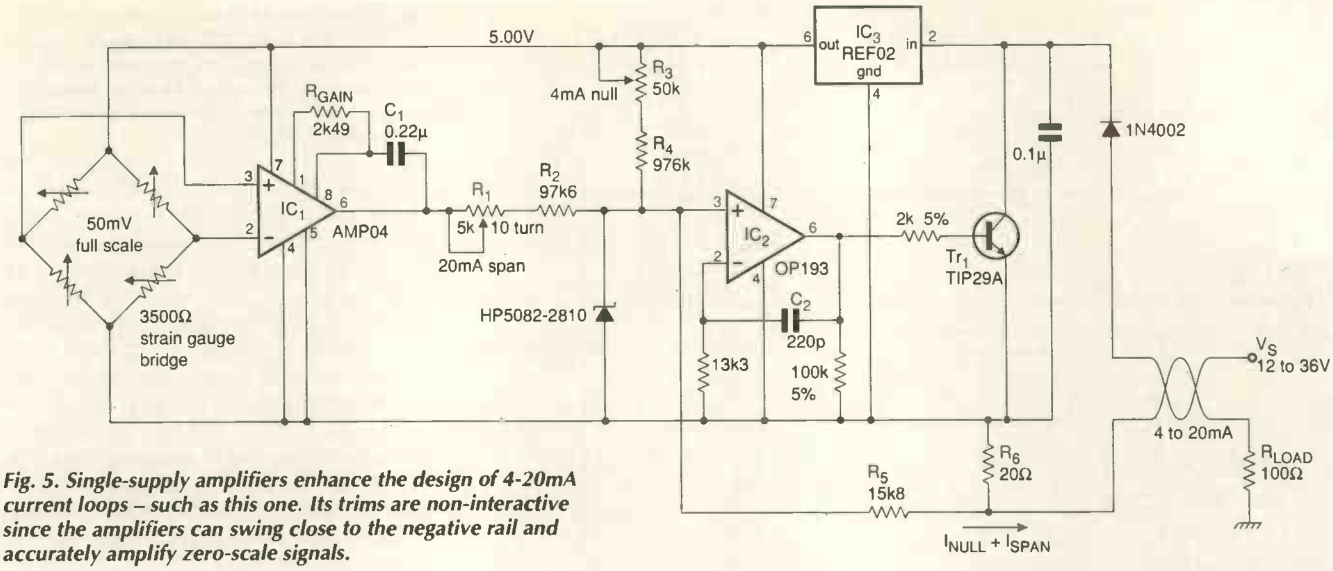


Fig. 5. Single-supply amplifiers enhance the design of 4-20mA current loops – such as this one. Its trims are non-interactive since the amplifiers can swing close to the negative rail and accurately amplify zero-scale signals.

flows into the summing point of IC_2 via $R_{1,2}$, since the summing point is servoed by IC_2 to this same potential. For this zero scale signal condition, the loop is calibrated via R_3 (null) for a 4mA output current, or 0.4V across R_{LOAD}. Because current in R_1 is zero for this condition, it has no effect on the null trim, thus making the null/span trims non-interactive.

Resistors $R_{3\text{-}4}$ effectively appear across the 5V reference voltage from IC_3, so the current injected is constant and scaled upward by loop output summing resistors, $R_{5,6}$. The expression for this current, I_{NULL}, is,

$$I_{NULL} \approx \left[\frac{5}{R_3 + R_4}\right]\cdot\left[\frac{R_5 + R_6}{R_6}\right]$$

where 5 represents the IC_3 reference voltage.

As the system sees a 50mV full-scale bridge output, this is amplified to a 2V level by IC_1, which then supplies signal current to the IC_2 summing point. Like the reference current through $R_{3\text{-}4}$, signal current in $R_{1\text{-}2}$ is scaled up by the loop, and appears in R_6 as I_{SPAN}, or,

$$I_{SPAN} \approx \left[\frac{V_{BRIDGE} \times G}{R_1 + R_2}\right]\cdot\left[\frac{R_5 + R_6}{R_6}\right]$$

where V_{BRIDGE} is output of the bridge, and G is gain of the *AMP04* op-amp. In this case trimming is done via potentiometer R_1 (span) with a 50mV full-scale bridge output, for a 20mA output current (4mA I_{NULL} plus 16mA I_{SPAN}), or 2V across R_{LOAD}.

In this circuit the three active devices and the 3500Ω bridge consumes 3.75mA of current worst case – safely below the 4mA zero scale of the system. Capacitor C_1 provides a 7Hz low pass, to limit noise, while C_2 stabilises the IC_2 output loop.

The 0-16mA I_{SPAN} portion of the loop output is conducted by Tr_1, a TO-220 device. The low drift at typically 0.2µV/°C of the *OP193* used at IC_2, along with the low quiescent power of 15mA, aid overall performance of this circuit.

Digital-to-analogue on a 5V rail

Most d-to-a converters are designed for dual supply operation. Of those which are not, most work on supplies of 12-15V, as opposed to 5V only. This greatly reduces the component choices available for single +5V supply system power.

Complementary-mos *R*-2*R* ladder converters are natural choices for low voltage operation, as many of these units are designed to work on 5V supplies. However, when used in their standard multiplying mode with an inverting output amplifier, they also require a negative supply for the amplifier, in order to output negative voltage with a positive reference. Conversely, if a negative reference is used, the output is positive range. In either case a negative supply is required.

In order to make such a d-to-a converter operate totally unipolarly, it can be turned around and operated in what is known as its inverted, or voltage-output mode. With the IC_1 *DAC8043* pinout shown in **Fig. 6**, in this mode V_{REF} input to the ladder becomes the voltage output node, pin 1, and normal I_{OUT} node becomes the reference input, pin 3.

This voltage mode c-mos d-to-a converter circuit works on 5V only, using two eight-pin

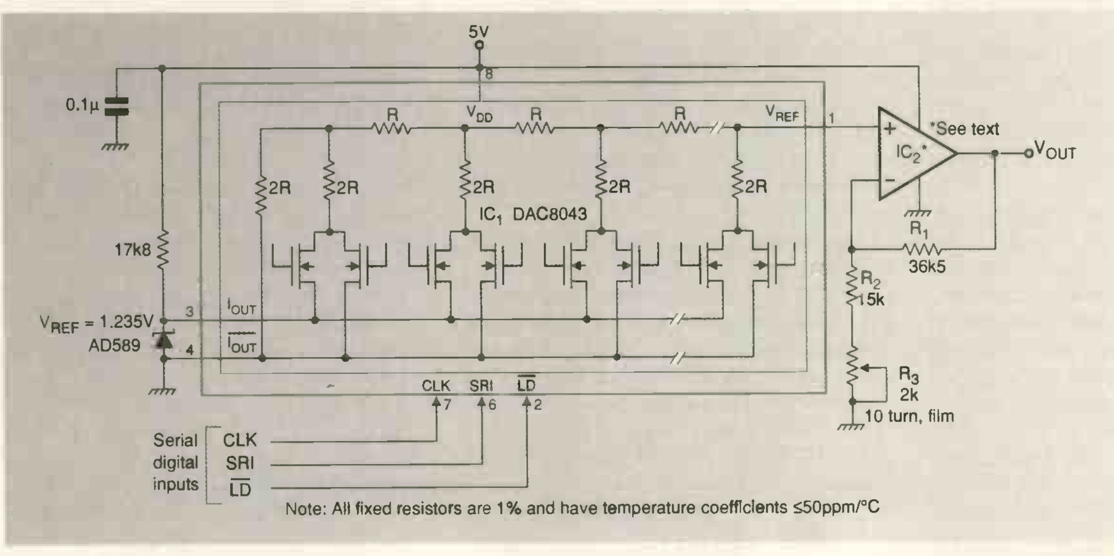


Fig. 6. To run a standard c-mos R/2R ladder d-to-a converter from a single supply rail, you need to operate the converter in its inverted, or voltage-output, mode.

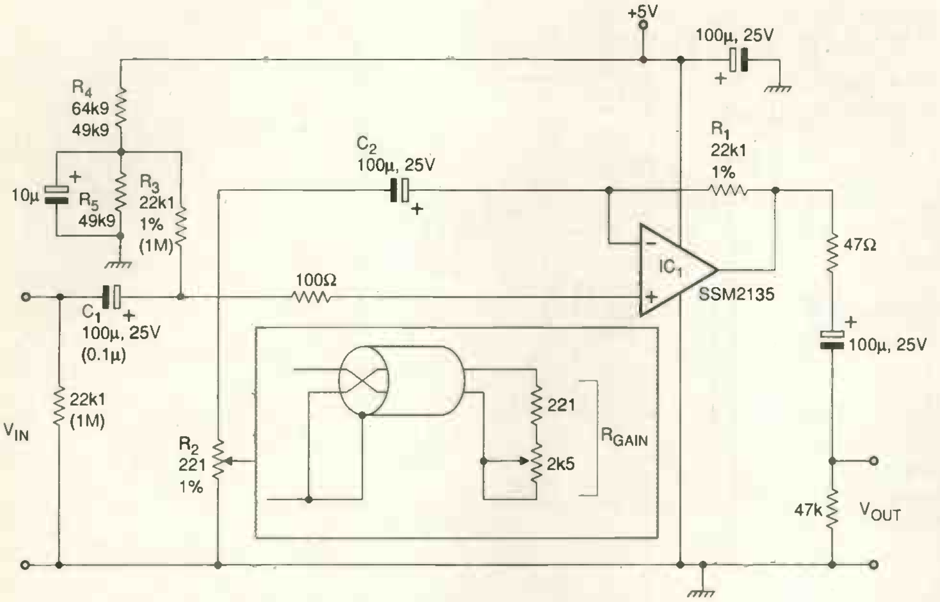


Fig. 7. Devices and circuit topologies make achieving low noise difficult in single-supply designs. One critical design technique is to limit resistor noise using low-noise resistors, or by adding bypass capacitors across them, as this circuit does for R_5.

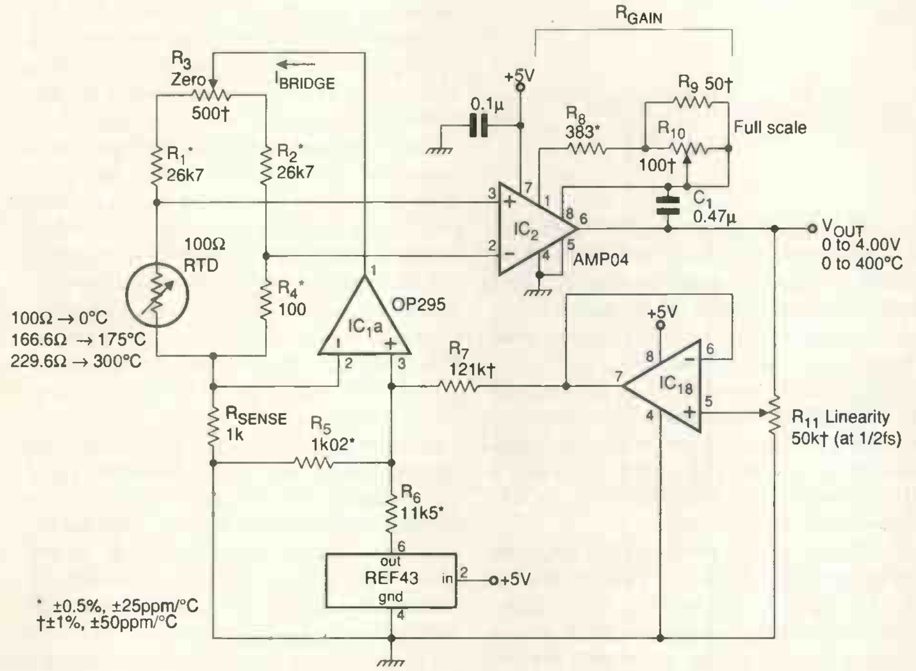


Fig. 8. Overall current drain of this thermometer design is 1.3mA. The circuit yields a 0 to 400°C output working from a 5V supply and 0 to 350°C from a 4.5V supply.

ICs to achieve serial input 12bit operation. It is scaled for a 0-4.095V output range, or 1mV/lsb. Digital inputs are ttl compatible, and the circuit uses a low component count. A number of output amplifiers can be used for IC_2, as noted below.

While the circuit is clean and straightforward, some application points are noteworthy in the interests of maximising performance. Note that with only a 5V supply, the internal n-mos switches have only 5V–V_{REF} as enhancement voltage, or 3.765V with a 1.235V reference. Therefore 1.3V for V_{REF} is about as high as can be applied to the d-to-a converter operating in this fashion.

If higher V_{REF} voltages are used, the mosfet gate drive can become starved, leading to higher on resistance and output voltage non-linearity.

This circuit uses an *DAC8043*. Because this is a 12bit multiplying d-to-a converter, the output voltage will be $(D/4096)\times V_{REF}$, where D is the 12bit digital word ranging from 0-4095. With a V_{REF} of 1.235V, unbuffered output at pin 1 of IC_1 will be (4095/4096)×1.235V at full scale, or about 1.2347V, which is around 300μV/lsb.

Output amplifier IC_2 brings the overall scale seen at V_{OUT} up to the desired 1mV/lsb. Gain required of IC_2 for this weighing is about 3.3, and is made variable to trim out tolerances in both V_{REF} and the gain resistors. Also, for bipolar amplifiers IC_2, it helps to make the equivalent resistance of the gain divider equal to the d-to-a converter output resistance of around 11kΩ. This has been done for the $R_{1\text{-}3}$ values shown.

Accuracy at dc, speed and power are strongly affected by the choice of IC_2, and some tradeoffs may be necessary for the best overall choice. Relatively slow response and good overall dc accuracy is possible with the *OP295*, or faster response with good but somewhat reduced accuracy with the *AD820*.

For a linear V_{out} range of 0 to 4.095V, the amplifier must be a rail-to-rail output stage type such those shown in Fig. 1. The *OP295* has a maximum V_{os} of 300μV, so the worst case output offset will be about 1mV; with the *AD820* this is raised by a factor of 1.67 – optionally nulled if desired. If the low offset *OP284* is used, the output offset error can easily be kept below 1lsb.

All amplifiers mentioned can source a 4.095V output on 4.75V, with current as noted in the table of Fig. 1. The rail-to-rail output stages allow linear swings close to ground. For the *OP295*, the c-mos output stage allows linear outputs down to within 1mV or lower, while the bipolar output types pull down to about 10mV or lower. Note that the $R_{1\text{-}3}$ gain-set resistances act as a pull-down, as do any external loads to ground.

With the amplifier selection, there is a an intrinsic speed/power tradeoff. Settling time using the *OP295* is under 150μs, but this can be improved with the *AD820* or *OP284* to about just a few microseconds, due to their much higher slew rate. The tradeoff here is power; an *OP295* channel with the d-to-a converter consumes about 660μA, while the faster *AD820* or *OP284* use more than 1mA.

Note that the output amplifier function can also be satisfied with more specialised circuitry for specific applications. For example, a buffered amplifier-pass transistor combination such as that used in Fig. 4 allows a programmable power supply with high current output characteristics to be readily implemented, by replacing the fixed reference of that configuration with the voltage variable source from the *DAC8043*, pin 1. By choosing the scaling of the buffer amplifier accordingly, a wide range of output swings is possible.

Low-noise single supply amplifiers

It is much more difficult to achieve low noise operating on single supplies than with dual supplies – for various reasons.

Many single-supply devices limit low-level performance, because of low-current internal biasing which compromises voltage noise in bipolar stages. For example, input noise densities of 40-50nV/√Hz are not uncommon for low power devices. Also, single supply amplifier configurations can themselves limit noise, due to biasing and other non-ideal issues absent in dual supply designs.

Figure 7 is a design which addresses these difficulties – a single supply ac amplifier, arranged for low-noise operation from either low or high-impedance sources. Because of single-supply operation, input and output coupling is of necessity via capacitors, three in the circuit itself and two more for bypassing.

Amplifier IC_1 can be half of an *SSM2135* dual, an *AD820*, or half of an *AD822*, depending on the source impedance. All of these are low noise units suitable for 5V and higher single supply operation.

The SSM2135 features a 6nV/√Hz input noise, comparable to the popular *5532*, which does not operate optimally on low voltage single supplies. The *AD820/AD822* single/dual types have about 12.5nV/√Hz voltage noise. Current noise of the *SSM2135* is 0.3pA/√Hz, while the *AD820/AD822* current noise is only 0.8fA/√Hz, due to its fet input stage. Thus the *SSM2135* is preferred for source impedances below approximately 10kΩ, and the *AD820/AD822* are generally better when the source is above 10kΩ.

To achieve lowest circuit-related noise, the IC_1 gain resistance R_2 is set by design to a value which has a Johnson noise $^1/_3$ that of the *SSM2135*, or 221Ω (2nV/√Hz). This step ensures that the noise of the amplifier will dominate at high gains with very low source resistances, rather than the adjoining circuit.

For lowest noise in the surrounding circuit, biasing must also be noiseless, that is free from noise added directly or indirectly by the biasing.[3] This means resistors with dc across them should have low excess noise, or be ac-bypassed. As a result, $R_{1\text{-}5}$, are metal film types, and $R_{4,5}$ are bypassed. A 2.2 or 2.5V bias source is provided from $R_{4,5}$, which biases the output of IC_1 for optimum swing. In addition, C_1 and C_2 are low esr types.

To provide a low source impedance for lowest noise, C_1 must be larger than if chosen strictly from a time constant point of view (100µF). Otherwise, current noise from a bipolar amplifier such as the *SSM2135* might produce an equivalent low-frequency voltage noise, across C_1 and R_{SOURCE}.

Because of the very low current noise and bias current of the *AD820/AD822*, when they are used, this allows the input impedances to be much higher, and C_1 can be correspondingly smaller (0.1µF). Component values in parentheses apply to an *AD820* or *AD822*.

Gain of the stage as shown is 100 with the fixed value of R_2. However a remote gain function can be optionally provided by using the variable network, R_{GAIN}. Bandwidth of this amplifier with the *SSM2135* is about 30kHz at maximum gain, and about 20kHz with the *AD820* or *AD822*.

Apart from the source impedance choice between these two types, there are some power consumption differences; the *SSM2135* draws a quiescent current of 1.45mA/channel, while the *AD820* or *AD822* current is about 700µA/channel.

With the two sections of the duals available, the circuit is useful as a low level preamp for multi-media or other 5V supply audio applications. Noise performance will reflect the device chosen for IC_1, and the relative source impedance. With a shorted input, the *SSM2135* measures an output noise of about 110µV rms at a gain of 100, and thd+n was 0.022% at a 1V rms output level into a 2kΩ load. Under similar conditions, the *AD820* measures about 200µVrms with 0.05% thd+n.

Precision temperature sensing

Many methods of sensing temperature are available, but very high precision on single power supplies remains a challenge.

Figure 8 shows how a precision platinum resistance temperature device, or rtd, can be implemented on a single 5V supply. The rtd bridge is driven with a total regulated I_{BRIDGE} current of 200µA. This minimises the rtd self-heating, by virtue of the 100µA excitation. Overall circuit current drain is 1.3mA and the circuit works from supplies of 5V for a 0-400°C output, or down to 4.5V for a 0-350°C range.

The 200µA I_{BRIDGE} current passes through R_{SENSE} and is compared to the 0.2V reference voltage appearing across R_5. The IC_{1A} control amplifier is an *OP295*, which easily allows input voltages of 0.2V, and the rail-rail output provides ample headroom to drive the bridge.

At the bridge output, the common mode voltage is around 0.201V – a level difficult to handle for a conventional 5V instrumentation-amp, whether IC or discrete. In this circuit the output is amplified by IC_2, an *AMP04*. This device has an input common-mode range of 0-3.5V and a output range of 0-4.2V while operating on 5V.

Gains of 1-1000 are set by a single external resistor, R_{GAIN}. The *AMP04* gain is simply equal to 100kΩ/R_{GAIN}, so in the case here it is nominally 245. This gain times the bridge output voltage of 38µV/°C yields a V_{OUT} scale factor of 10mV/°C. Capacitor C_1 provides a low-pass filter function in conjunction with the internal *AMP04* 100kΩ resistor, so the signal is low pass filtered above 3.4Hz.

Several factors are important in the associated circuit for best performance. All critical resistors, marked *, should be 0.5%, ±25ppm/°C types, or about 100 times better than the rtd temperature coefficient of 3850ppm/°C. Resistors $R_{1,2}$ in particular should be same batch/same manufacturer units, with R_4 also same manufacturer. These measures help minimise differential temperature coefficients.

Gain resistor R_8 should have a temperature coefficient which is low with respect to the *AMP04* coefficient of 50ppm/°C. Less critical resistors, market †, with smaller percentage error contributions can be more loosely controlled. All potentiometers should be multiple-turn film types.

The bridge/amplifier combination has a small amount of non-linearity, typically around 0.5%. In comparison, the rtd has a much larger non-linearity, as much as 6°C over a 400°C span, or 1.5%. Fortunately, this non-linearity can be corrected with controlled positive feedback which increases the bridge drive with increasing output. To implement this, a fraction of V_{OUT} is picked off by R_{11} (linearity), is buffered by IC_{1B}, and then is summed with the 0.2V reference voltage via R_7. With correct adjustment, this feedback cancels the rtd non-linearity.

Calibration is a relatively simple three-step process. First, care must be taken in the setting for 0°C, for the simple reason that the lack of a negative supply prevents this end point going through 0V.

One technique, step 1, is to substitute an exact 100Ω resistor for the rtd, or place the actual rtd in an ice bath solution, and adjust zero-setting resistor R_3 until V_{OUT} begins to swing positive. Next, trim R_3 in the reverse direction until V_{OUT} just stops changing, which should be zero volts.

For full-scale trim, step 2, preset R_{11} to a midpoint and substitute a 274.04Ω resistor for the rtd. Then trim R_9 for 4.000V at V_{OUT}, which represents 400°C. For setting linearity, step 3, substitute a 175.84Ω resistor for the rtd, and trim R_{11} for 2.000V at V_{OUT}. Steps 2 and 3 should be repeated for best accuracy, as they interact.

When fully trimmed, the output errors of the circuit are within ±0.5°C over the 0-400°C range.

Monitoring current supply

Single supply amplifiers can be arranged to make accurate current monitors in either a negative or positive supply lead. The circuits

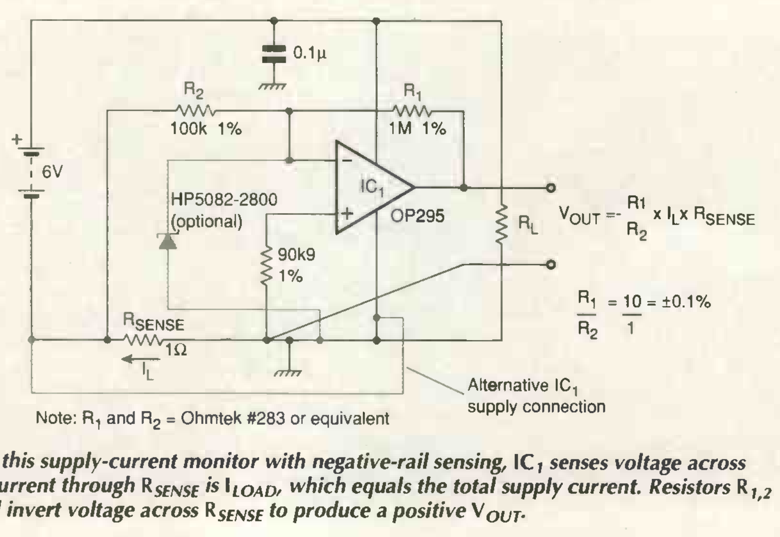


Fig. 9. In this supply-current monitor with negative-rail sensing, IC_1 senses voltage across R_{SENSE}. Current through R_{SENSE} is I_{LOAD}, which equals the total supply current. Resistors $R_{1,2}$ scale and invert voltage across R_{SENSE} to produce a positive V_{OUT}.

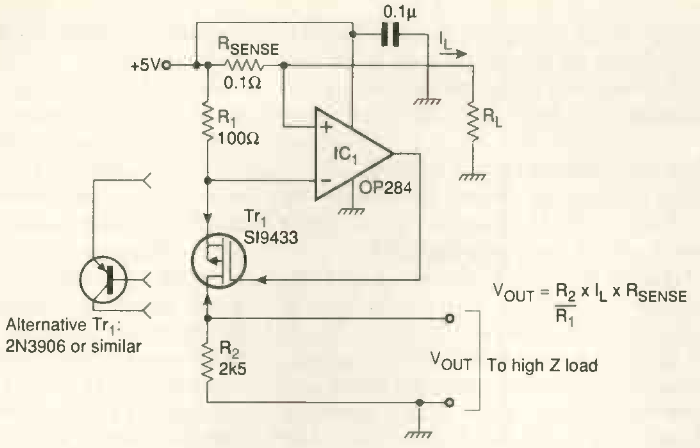


Fig. 10. In this positive-rail sensing supply-current monitor, IC_1 senses voltage across R_{SENSE}. Voltage across R_1 is forced equal, and $R_{1,2}$ scale output voltage. The transistor shifts level and produces ground-referred output V_{OUT}.

below deliver output voltages directly proportional to load current and positive with respect to supply ground. They are adaptable for wide operating current ranges.

An easy way to monitor negative rail supply current with a single supply amplifier is shown in **Fig. 9**. Here IC_1 is a section of an *OP295* arranged to sense voltage drop across R_{SENSE} in the negative supply lead. Current through R_{SENSE} is I_L – the total supply current. Resistors $R_{1,2}$ scale and invert the voltage across R_{SENSE}, producing a positive output, V_{OUT}.

Because of the ability of IC_1 to sense inputs close to its negative supply rail and a rail-rail output capability, the circuit responds linearly to small currents down to a V_{OUT} level of a few millivolts. Current-to-voltage conversion scaling is set by the choice of resistor R_{SENSE} plus the R_1/R_2 ratio, producing 10mV/mA or 1V=100mA output scale factor as shown here.

Resistor R_{SENSE} is adjusted proportionally for other scale factors, such as 0.1Ω for 1mV/mA, 0.01Ω for 0.1mV/mA, etc. Full scale will be essentially dictated by the supply voltage. For example the 6V supply shown allows currents to be monitored up to 600mA. Resistors $R_{1,2}$ should be ratio matched for lowest gain error, and stable types should be used for both these and R_{SENSE}.

For highest performance, some other factors should be considered. For low power losses and sense errors, drop across R_{SENSE} should be 100mV or less. As shown, the relatively low 160μA/channel *OP295* supply current is part of I_L, but it can be alternately bypassed around R_{SENSE} if needed. A Shottky diode clamp is suggested for IC_1, if input transients can take the summing point 0.3V or more below ground.

The circuit of **Fig. 10** allows positive rail sensing, by placing the R_{SENSE} resistor in series with the positive rail to be monitored, such as +5V, etc. This requires an op-amp which can operate with common-mode inputs near the positive rail, such as the *OP284* shown for IC_1.

This circuit uses the op-amp plus a high current gain transistor such as Tr_1 to sense the drop across R_{SENSE}, which the loop duplicates as an equal drop across R_1. With the connection of a high gain Tr_1 as a follower, the drain current is then equal to the current in R_1. Output, V_{OUT}, is then proportional to I_L, and referred to the common end of R_2, or ground.

Interestingly, the overall expression for V_{OUT} follows the same form as that of Fig. 9. In this case, with 0.1Ω for R_{SENSE} and $R_{1,2}$ as shown, the sensitivity is set up as 2.5V/A.

Caveats similar to those of Fig. 9 apply to selecting R_{SENSE} for a full scale drop of less than 0.1V, and the general precision of $R_{1,2}$. The op-amp should also have a low offset voltages, which is true in the case of the *OP284*. Additional caveats apply to the gain of Tr_1, which ideally should be a mosfet such as the low threshold device listed.

Since the effective β of an fet is near infinite, the entire current passing through R_1 also passes through R_2, and develops an accurate output. Note that since this is a current output, R_2 can be returned to a remote load for best accuracy.

At the expense of accuracy, the circuit can be simplified by substituting a high-gain PNP transistor such as the *2N3906* for Tr_1. Note that since the output of this circuit is unbuffered, any shunt resistance across R_2 will change the overall scale factor. Therefore V_{OUT} should drive a high impedance input such as a buffer stage, or a non-loading a-to-d converter input.

A composite instrumentation-amp

As noted earlier, high performance linear circuits operating from 5V and lower supplies are common in many modern designs. While there are many precision rail-to-rail op amps, plus some good single-rail compatible in-amps such as the *AMP04* (above), it is generally true that achieving the very highest levels of performance today requires the use of devices expressly designed for conventional dual-supply operation.

It may seem a contradiction in terms to make such a statement, however, as will seen, clever interfacing allows such a precision dual supply device to provide accurate, high dynamic range outputs while operating on a single 5V supply.[4,5]

A technique allowing high precision with single-rail operation takes advantage of the fact that popular transducers such as strain gauge bridges provide an output signal which is naturally centred around the mid-point of the excitation voltage. When the supply rail is used as excitation for these bridge type circuits, the inputs of the signal conditioning in-amp then see a common-mode voltage equal to half the rail voltage.

For single 5V rail operation, this implies a common-mode level of 2.5V, which the amplifier sees as equal to a common-mode voltage of zero when operated on ±2.5V supplies. What is needed to implement this type of system is an in-amp 'front end' which has very high precision on a 5V supply, plus an

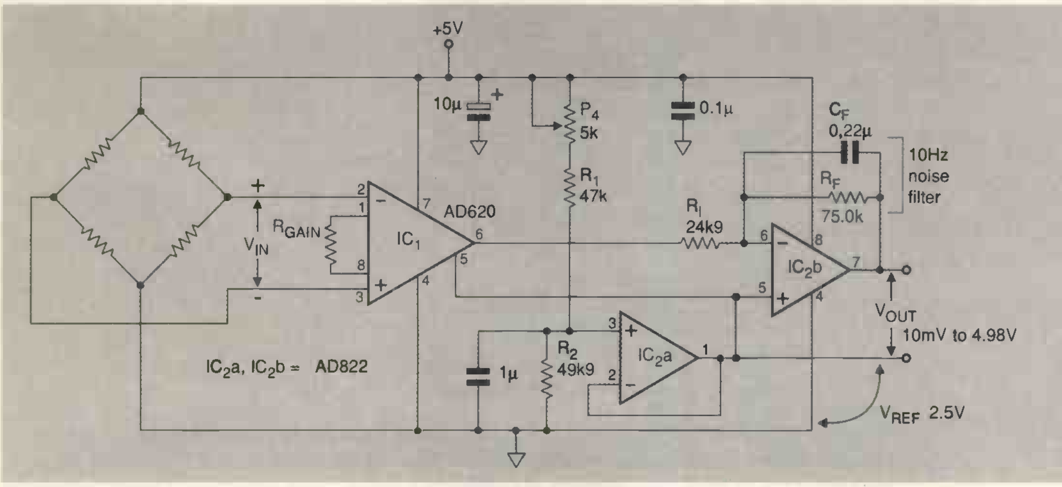


Fig. 11. Precision instrumentation amplifier capable of operating from a single low-voltage supply. Rail-to-rail output is made possible by the precision instrumentation amplifier IC_1 and a rail-to-rail-performance buffer, IC_{2B}.

output buffer stage which can be set up to provide rail-to-rail output. This greatly enhances overall dynamic range and dc precision.

Fig. 11 shows such a high performance in-amp which operates from a single +5V rail, and senses signals from a bridge. The circuit uses the *AD620* IC in-amp for the input stage, IC_1. It also uses a dual IC for the second stage, $IC_{2A,B}$ – sections of an *AD822*. The IC_{2B} stage is used for voltage scaling and buffering, providing a rail-to-rail output swing. The stage around IC_{2A} is a unity-gain buffer for V_{REF}, which drives the reference input of IC_1 and also provides an 'elevated ground' potential for circuits following.

Resistors $R_{1,2}$ form a voltage divider, nominally splitting the supply rail to around 2.5V, with optional adjustment via trimmer P_1. This voltage is applied to the input of IC_{2A}, using the fet input *AD822*, thus providing buffering and a low-impedance source for the *AD620*'s output reference port at pin 5. Note that a low source resistance here is critical to maintain high common-mode rejection, so this buffer stage is important.

The other half of IC_2 is connected as a fixed inverting gain stage which scales the signal by a factor of three. This guarantees that a 5V pk-pk or 'rail-to-rail' output from the IC_{2B} stage will only need a 1.67V pk-pk drive from IC_1. This output swing is well within the *AD620*'s capability, which in turn ensures highly linear operation from the IC_1 stage.

As is noted in the diagram, V_{OUT} is referenced to V_{REF}, as opposed to power ground. The active V_{OUT} range of 0.01-4.98V on a 5V supply essentially means the circuit processes outputs of up to ±2.5V linearly with respect to the +2.5V elevated ground. Over an operating gain range of 10-1000 and the rail-rail signal swing noted, the linearity of this composite in-amp is better than 0.005%.

Gain G of the composite amplifier is the product of the IC1 and IC2B stage gains, or simply,

$$G=\left[\frac{49.4k\Omega}{R_{GAIN}}+1\right]\cdot\left[\frac{R_F}{R_I}\right].$$

In this expression the 49.4kΩ value is an internal resistance of the *AD620*. Resistors R_F and R_I are the resistances around the IC_{2B} gain stage, and R_{GAIN} is the user selected gain set resistor connected between pins 1-8 of IC_1. With a fixed gain of 3 in stage IC_{2B}, it turns out that standard 1% values for R_{GAIN} allow convenient overall gains, such as 21.5kΩ ⇒ G=10, 1.53kΩ ⇒ G=100, etc.

In this +5V powered application, the total input common-mode voltage applied to the inputs of the *AD620* can be in the range of +2.1V to +3.7V for full rated performance. Operating this circuit then at an overall gain of 10, the common-mode input voltage span is such that the inputs can readily accommodate the required 0.5Vpk-pk signal centred about a nominal 2.5V level.

The inverting configuration was chosen for the output buffer to facilitate system output offset voltage adjustment by summing currents into the buffer's feedback summing node. These offset currents can be provided by an external d-to-a converter, or from a resistor connected to a reference voltage.

The *AD822* rail-to-rail output stage exhibits a very clean transient response, not shown, and a small-signal bandwidth over 100kHz for gain configurations up to 300.

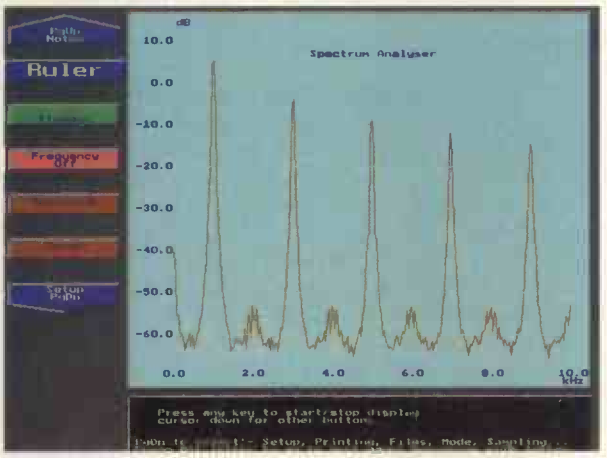
To reduce noise effects, an optional capacitor C_F is recommended in this IC_{2B} stage. This forms a simple low pass filter in conjunction with R_F, with the values shown placing the corner frequency at 10Hz. Also, to help minimise the effects of high frequency input-stage rectification, additional common-mode filtering can be used prior to the IC_1 inputs. ■

References

1. Walt Kester & ADI Staff, 'Practical Analog Design Techniques', Analog Devices Seminar Notes, 1995.
2. Walt Jung, 'Low Dropout References and Regulators', within Chapter 9 of Ref 1.
3. Motchenbacher; F. Fitchen, 'Low-Noise Electronic Design', Wiley, New York, 1973.
4. Lew Counts, Product Line Director, Advanced Linear Products, Analog Devices, Inc., personal communication, 1995.
5. Adolfo Garcia, 'Single Supply Amplifiers', Chapter 1 within Ref 1.
6. C. Kitchin and L. Counts, 'Instrumentation Amplifier Application Guide', Analog Devices, Inc., 1991.

Add senses to

Plugging into a pc printer port, these two a-to-d converter interfaces provide a simple and economical way of providing virtual instrumentation and data logging.



Software for creating a spectrum analyser is primarily designed for use with the faster ADC-100, but it can also be applied with the ADC-11 to form a simple oscilloscope, frequency counter, voltmeter and spectrum analyser.

Virtual instruments – computer based test instruments – comprise two main components. One is interface hardware connecting to the computer and the other software that simulates the functions of the instrument. By simply changing the software, the computer can become an oscilloscope, voltmeter or spectrum analyser.

Consider three different test instruments - a digital storage scope, spectrum analyser and a logic analyser. Although they all perform different functions, each of these expensive items contain much of the same inside – a display, keypad, processor and power supply.

Rather than buy three separate displays, three keypads and three power supplies, it makes sense to use those you already have in your computer. All the hardware you need to buy is a data acquisition interface.

With a disk drive to save waveforms and a printer already connected, virtual instruments give additional advantages.

The division between data logging and virtual instrumentation is fuzzy. Often the same hardware can be used for both. The *ADC-11* described here was designed primarily for data logging with *PicoLog* software, but it can also be used with *PicoScope* software to create a simple oscilloscope. Similarly the *ADC-100* was designed as a virtual instrument using *PicoScope*, but can also be used as a data logger with *PicoLog*.

Pico data converters

Most data acquisition devices are plug in cards. Pico devices differ in that they plug directly into either the serial or parallel port, depending on the model, and require no power supply. This means that they can be installed in seconds and are ideal for use with portable personal computers.

Available software includes *PicoScope* for use as a Virtual Instrument and *PicoLog* for datalogging. For users wanting to write their own software, C, Pascal, Visual Basic and Windows DLL drivers are supplied as standard.

Data logging with the *ADC-11*

The *ADC-11* provides eleven channels of analogue input in a case slightly larger than a matchbox. Each channel accepts inputs in the range 0 to 2.5V and provides a resolution of 1 part in 1023, i.e. 10bits.

Basic accuracy of the device is 1% and it can take up to 15,000 samples a second. A digital output is also available for control/alarm functions, which can alternatively provide power for sensors such as thermistors.

The ADC-100 virtual Instrument

The *ADC-100* has been described as 'a complete electronics lab in your pc'. With the supplied *PicoScope* software, you can use your pc to emulate the following instruments:

- dual-channel storage oscilloscope, 100μs/div to 5s/div
- XY mode oscilloscope
- spectrum analyser, 0-50kHz
- voltmeter, ac/dc or dB
- frequency meter, 0-30kHz.

Plugging directly into a pc parallel port, the *ADC-100* offers both a high sampling rate of 100kHz and a high resolution of 12bits. Nine input ranges, providing ±50mV to ±20V full scale, enable the unit to be directly connected to a wide range of signals.

As well as its use as a general purpose laboratory instrument, the *ADC-100* has proved popular in many diverse fields. For example they are used in garages for tracing faults in modern car electronics, ie ignition, fuel injector and ABS circuits. In addition, they prove invaluable to audio engineers as the spectrum analyser covers the whole audible range.

Spectrum-analyser capabilities of the *ADC-100* a-to-d converter together with the *Picoscope* software are illustrated above. This same software also turns the pc into a dual-channel or XY-mode oscilloscope, voltmeter or frequency counter. The spectrum analyser display shows harmonics of a square wave.

Battery discharge

An example of simply measuring a voltage is plotting the discharge curve of one or more batteries. This is often used as a test to see if rechargeable batteries are coming to the end of their useful life, or to compare the capacity of two different types.

For this example two different types of 6V mobile phone batteries were fully charged, then discharged, while being monitored by the *ADC-11*. *PicoLog* software was used to show a real time graph of the discharge.

The attenuator needed is shown, together with a graph of the results. Resistor R_1 is used as a load resistor to discharge the battery while $R_{2,3}$ form a

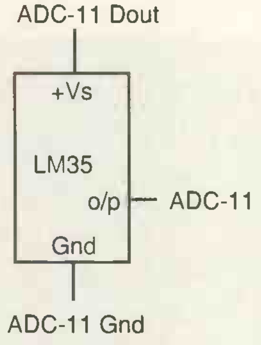
your PC

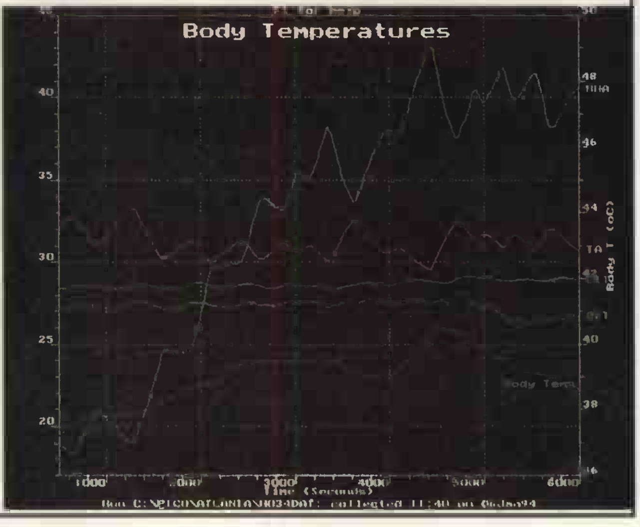
Monitoring temperature

Temperature is the most commonly measured 'real world' signal in data logging. The *ADC-11* works well with either thermistors or semiconductor sensors. For a thermistor, only a simple potential divider circuit is needed.

A common semiconductor temperature sensor is National Semiconductors *LM35*, which gives an output of 10mV/°C. As its power requirements are low, it can be powered using the *ADC-11*'s digital output. With an *ADC-11*, you can measure temperatures in the range 2°C to 110°C with an accuracy of better than 1°C.

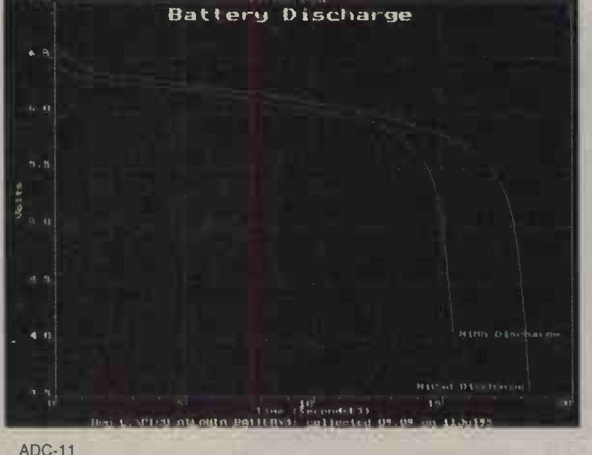
An optional terminal board for the *ADC-11* has space for an *LM35* to allow quick and easy connection. Once connection is made, the *PicoLog* software can display and record the temperature. The circuit for connecting the *LM35* to the *ADC-11* is shown.

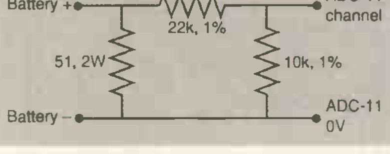




Monitoring body temperature on the pc is simply a matter of plugging the a-to-d converter into the printer port and wiring in a sensor.

simple potential divider to increase the *ADC-11* input range from 2.5V to 8V. The plot shows that the nickel-metal-hydride battery, although much smaller than the nickel-cadmium battery, has virtually the same capacity.





Monitoring battery charge or discharge is simply a matter of connecting the battery terminals to the a-to-d converter via a suitable potential divider.

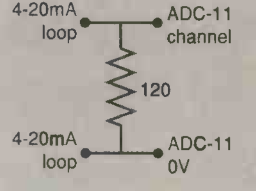
Current loop sensing

Most industrial sensors have current-loop outputs. Normally these are 4-20mA loops. A value of 4mA corresponds to a zero signal and 20mA corresponds to full scale.

Currents below 4mA or above 20mA signal error conditions, such as a failed sensor or broken wire. *Picolog*'s alarm functions can be used to give warning of these. Current loops are used rather than voltage signals as they are less subject to electrical noise and unaffected by cable length.

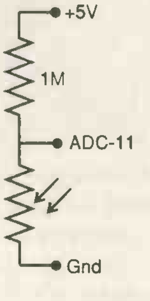
The easiest way to monitor a current is to measure the voltage developed across a resistor inserted into the circuit. Here, a 120Ω resistor allows currents just over 20mA to be monitored. Remember that the *ADC-11*'s 0V is effectively mains earth, assuming a mains powered pc. As a result, check with the sensor manufacturer whether it is permissable to ground part of the current loop.

In 4-20mA loop systems, apearance of currents below 4 or above 20mA signal an error condition. Via one resistor, Pico allows 4-20mA monitoring on the pc, together with an alarm trigger when currents above 20mA are detected.



Detecting light levels

Light levels can be measured simply by connecting an *ORP12* or similar light-dependent resistor. In bright light, this device has a resistance of a few hundred ohms, so the voltage fed into the *ADC-11* is very low. In total darkness the resistance rises to several megaohms causing voltage to rise.



An ORP12 or similar connected to the pc via the a-to-d interface allows a wide spread of light level to monitored at low cost.

Converting humidity to frequency

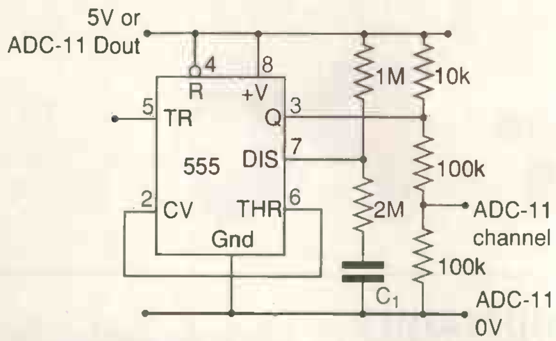
Two types of humidity sensor are available – resistive and capacitive. Resistive sensors are easier to use but tend to be less accurate.

The interface shown is based on a Phillips capacitive sensor, part no 2322 691 90001. If a c-mos *555* timer is used, the circuit can be powered from the *ADC-11* digital output. Alternatively, an external 5V supply is required.

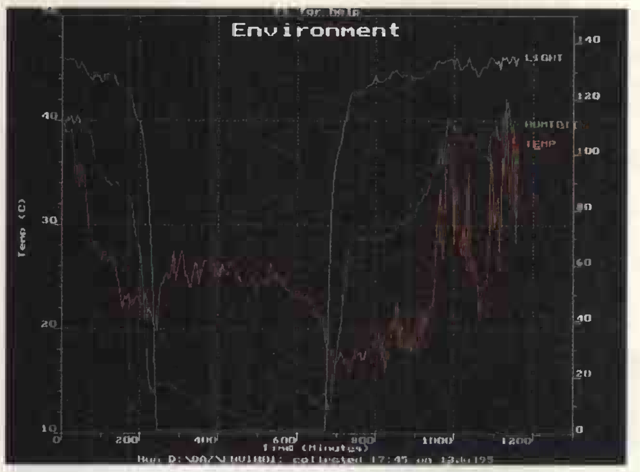
PicoLog software supplied with the *ADC-11* has the ability to record the frequency of the input signal. This is useful for sensors that generate pulse outputs such as flow sensors or for car engine rev/min measurement.

The humidity sensor is used as the timing capacitor in a standard *555* circuit. Output is a square wave whose frequency is related to humidity. Response of the humidity sensor is non linear, so a lookup table is required to convert frequency to a humidity proportionmally.

The photograph on the right shows a plot from *PicoLog* displaying humidity, temperature and light levels from the described circuits. ■



Capacitive humidity sensors are more difficult to use that resistive ones, but, they are also more accurate. This one changes output frequency of the astable timer for subsequent detection on the pc via the ADC-11.



Bringing together three of the sensors described here produces a versatile but low-cost data-logging system.

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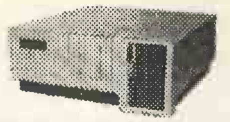

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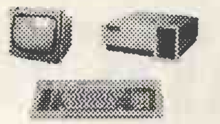

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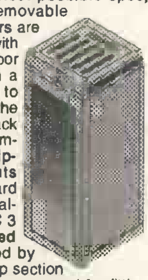

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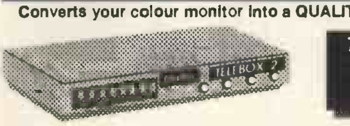

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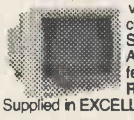

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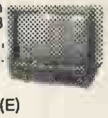

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APPLICATIONS

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Converting at video-speed without s&h circuitry

This high speed a-to-d flash converter is based on the *VP0158* from Gec Plessey, which requires no preceding sample and hold stage. Operating from a single 5V supply, the device is capable of digitising analogue signals with frequencies up to the Nyquist limit at a conversion rate of 25MHz.

Output data is available in four possible 8-bit formats, selectable via two digital control inputs, giving either true or inverted code in binary or offset twos' complement.

The typical application circuit shown is designed to accept a 1V pk-pk signal. Conditioning circuitry level shifts and multiplies the input signal to provide the converter's recommended 2V pk-pk drive signal, biased at 4.0V for optimum performance.

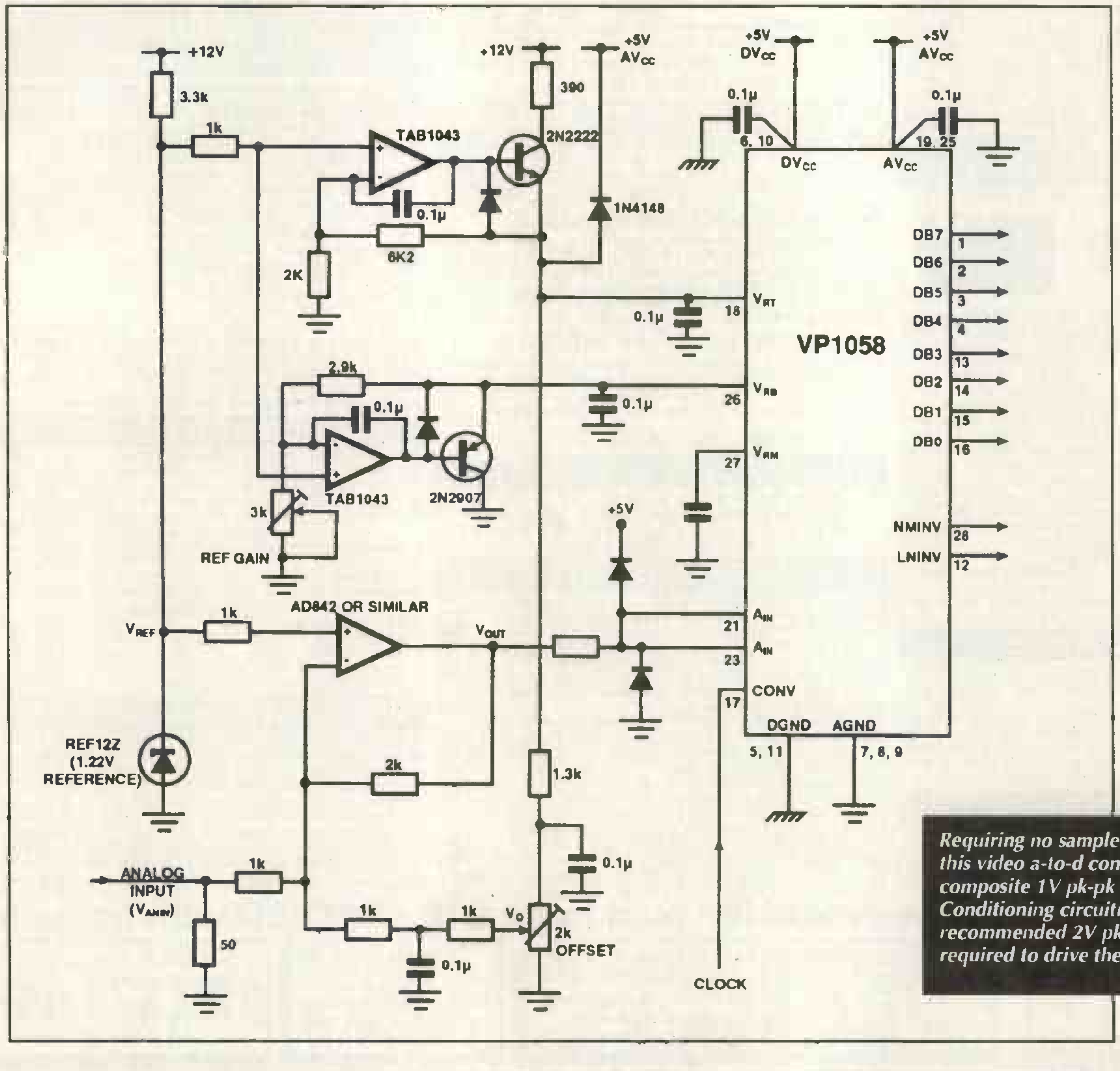
The analogue input amplifier, an *AD842* or similar, should be a wideband, high slew rate op-amp since it drives the A_{in} inputs directly. This device provides the necessary gain, offset and low impedance drive. A stable voltage level is needed for both input offset and gain control, in this case provided by a *REF12Z* micro-power reference.

The *VP1058* requires an external clock applied to the CONV input to determine the conversion sampling rate. This input synchronises the sampling, conversion and output stages of the devices.

Features of the chip include a 60MHz −3dB analogue input bandwidth, ttl compatible, digital i/o, and low power consumption of typically 670mW.

This application is taken from the digital video section of GEC Plessey's new *Digital video & digital signal processing IC handbook*. Further sections in the book cover dsp building blocks, algorithm-specific dsp chips and video compression.

GEC Plessey Semiconductors, Unit 1, Crompton Road, Groundwell Industrial Estate, Swindon, Wiltshire, SN2 5AF. Tel 01793 518527/518566, fax 01793 518582.



Requiring no sample and hold stage, this video a-to-d converter accepts a composite 1V pk-pk signal. Conditioning circuitry provides the recommended 2V pk-pk signal required to drive the VP0158.

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AF139	30p
AF239	30p
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BB205B	24p
BC107	8p
BC108	8p
BC109	8p
BC109C	10p
BC140	20p
BC142	20p
BC143	20p
BC147	8p
BC149	8p
BC159	8p
BC160	30p
BC171	10p
BC172	10p
BC177	14p
BC178	14p
BC179	14p
BC182	7p
BC182L	7p
BC183	7p
BC183L	7p
BC184	7p
BC184L	7p
BC212	7p
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BC477	18p
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BC556	8p
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BC558	8p
BC559	8p
BC560	8p
BC637	20p
BC639	20p
BC640	20p
BCY33	200p
BCY34	200p
BCY70	16p
BCY71	16p
BCY72	16p
BD115	30p
BD124P	50p
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BD236	30p
BD237	21p
BD238	24p
BD239	30p
BD240	40p
BD241A	40p
BD243A	50p
BD244	50p
BD245	50p
BD246A	50p

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BD267	45p
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BD278	50p
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BD315	150p
BD317	150p
BD331	40p
BD332	40p
BD361	60p
BD362	60p
BD370	30p
BD371	30p
BD410	50p
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BF367	13p
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BF455	12p
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BF479	30p
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BF595	16p
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BF615	30p
BF617	30p
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BT146	99p
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BU208A	75p
BU208AT	200p
BU208D	130p
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BU226	120p
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BU325	55p
BU326A	75p
BU406	60p
BU406D	85p
BU407	55p
BU407D	75p
BU408	60p
BU408D	75p
BU409	85p
BU426A	70p
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BU505DF	90p
BU506	100p
BU506D	90p
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BU526	70p
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BU903	110p
BU920	100p
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BU930	130p
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BUT12	80p
BUT56A	75p
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BUX98A	350p
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MPSA13	15p
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OC35	350p
OC36	250p
OC45	50p
OC200	180p
R2008B	100p
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S2000A3	175p
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S2055AF	200p
S2530A	100p
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TIP29C	25p
TIP29E	40p
TIP30	25p
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BY448	20p
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OA91	10p
OA202	10p
IN4001	3p
IN4002	3p
IN4003	3p
IN4004	3p
IN4005	3p
IN4006	3p
IN4007	4p
IN4148	2p
IN5400	9p
IN5401	8p
IN5402	8p
IN5403	8p
IN5404	8p
IN5405	11p
IN5406	12p
IN5407	12p
IN5408	12p
RGP15	25p
RGP30	16p
SKE4F2/06	60p
SKE4F2/08	80p
SKE4F2/10	100p
SR2M	60p
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8 PIN	5p
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7918	30p
7924	30p
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78L12	24p
78L15	24p
78L18	24p
78L24	24p
79L05	35p
79L08	35p
79L12	35p
79L15	35p
LM309K	100p
LM317T	100p
LM323K	350p
78H08KC	800p
79H12KC	700p
79HGKC	800p
LEDs	
3mm	
RED	5p
YELLOW	8p
GREEN	8p
5mm	
RED	5p
YELLOW	8p
GREEN	8p
RECTANGULAR LEDs	
5mm x 2.5mm	
RED	5p
YELLOW	8p
GREEN	8p
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4N37	58p
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BR34 2A/400V	43p
BR36 2A/600V	44p
BR62 6A/200V	80p
BR64 6A/400V	72p
BR251 25A/100V	150p
BR252 25A/200V	165p
BR254 25A/400V	185p
BR256 25A/600V	200p
BR258 25A/800V	240p
BR351 35V/100V	185p
BR352 35V/200V	200p
BR354 35V/400V	220p
BR356 35V/600V	230p
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TIC126M 12A/600V	90p
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BT119	100p
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17089	200p
17127	200p
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Z80ASIO-2	210p
75107	65p
75110	75p
75113	100p
75122	110p
75154	100p
75162	700p
75182	95p
75183	95p
75195	185p
2114	150p
2532	200p
2716	100p
2732	200p
2732A	220p
2764	150p
27C64	200p
27128	150p
27256-25	150p
27512	300p
4116	80p
4164-15	80p
4164-12	90p
41256-15	80p
41256-12	100p
41256-10	110p
41464-12	150p
6116	80p
6264-10	210p
62256-12	300p
6502A	360p
65C02	930p
6522	280p
6800	210p
6802	220p
680	500p
36808	500p
6809	500p
6810	150p
6818	380p
6821	130p
6840	290p
6845	200p
6850	90p
8085A	300p
8086	500p
8088	480p
8156	300p
8224	240p
8226	240p
8250	750p
8251	200p
8253	160p
8257	220p
8271	3400p
8279	270p
8283	400p
8284	440p
8287	260p
8288	650p
8748	700p
8755	800p
8T26	95p
8T28	110p
LINEAR ICs	
AN203	210p
AN210	185p
AN214Q	170p
AN228	280p
AN252	150p
AN259	250p
AN262	140p
AN271	230p
AN274	250p
AN301	330p
AN303	250p
AN304	360p

Part	Price
AN315	210p
AN316	350p
AN360	100p
AN362	140p
AN366	150p
AN610	160p
AN3312	350p
AN3821K	600p
AN3822K	600p
AN3990K	300p
AN3991K	400p
AN5025	250p
AN5033	400p
AN5132	250p
AN5150	400p
AN5151	600p
AN5215	100p
AN5256	150p
AN5262	175p
AN5265	80p
AN5352	600p
AN5411	450p
AN5421	150p
AN5429	420p
AN5512	100p
AN5515	160p
AN5520	550p
AN5521	100p
AN5612	200p
AN5613	200p
AN5615	300p
AN5620	250p
AN5622	275p
AN5625	400p
AN5712	180p
AN5722	140p
AN5730	160p
AN5732	120p
AN5753	130p
AN5763	450p
AN5790	240p
AN5791	225p
AN5836	450p
AN5900	130p
AN6135	120p
AN6247	200p
AN6270	400p
AN6300	600p
AN6306	380p
AN6320	180p
AN6332	320p
AN6341	200p
AN6344	440p
AN6350	610p
AN6359	500p
AN6360	320p
AN6362	400p
AN6371	350p
AN6387	480p
AN6884	200p
AN7105	170p
AN7110	75p
AN7114	120p
AN7115	110p
AN7116	90p
AN7120	100p
AN7130	75p
AN7140	170p
AN7145	195p
AN7146	210p
AN7154	180p
AN7156	240p
AN7168	200p
AN7178	180p
AN7222	75p
AN7254	150p
AN7256	250p
AN7310	60p
AN7311	90p
AN7410	150p
AY3-1015	290p
AY3-1270	800p
AY3-1350	450p
AY3-8910	360p
AY3-8912	400p
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BA313	60p
BA333	80p
BA401	60p
BA402	50p
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BA514	160p
BA516	150p
BA521	100p
BA524	240p
BA526	180p
BA527	95p
BA532	100p
BA534	220p
BA536	150p
BA546	160p
BA612	120p
BA656	110p
BA658	350p
BA684	400p
BA685	400p
BA1310	160p
BA1320	75p
BA1330	120p
BA1360	180p
BA4403	220p
BA5101	350p
BA5102	140p
BA5204	200p
BA5402	180p
BA5406	180p
BA5408	180p
BA6104	250p
BA6208	175p

Part	Price
BA6209	85p
BA6304	120p
BA6305	140p
BA6410	220p
BA6411	250p
BA6993	150p
BA7001	150p
BA7004	200p
BA7007	200p
BA7021	180p
BA7022	350p
BA7751LS	150p
BA7752	250p
BA7755	150p
BA7767AS	155p
CA3011	110p
CA3048	190p
CA3052	190p
CA3054	95p
CA3085	135p
CA3088E	200p
CA3089E	150p
CA3090O	250p
CA3130S	100p
CA3134E	280p
CA3140E	38p
CA3160	85p
CA3189E	230p
CA3193E	230p
CA3260E	170p
CA3290E	150p
CX108	950p
CX136	600p
CX139A	750p
CX141	750p
CX145	725p
CX150B	325p
CX175	325p
CX187	825p
CX804A	775p
CX867	575p
CX868	525p
CX877	300p
HA1125	120p
HA1197	130p
HA1199	130p
HA1319	200p
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HA1339A	350p
HA1377	120p
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HA1389	210p
HA1392	120p
HA1394	170p
HA1397	200p
HA1398	240p
HA11219	280p
HA11221	180p
HA11225	130p
HA11235	120p
HA11251	190p
HA11423	140p
HA11724	650p
HA12002	220p
HA12003	250p
HA12005	180p
HA12017	100p
HA13001	110p
HA13002	200p
HA13006	400p
HA13007	400p
HA13108	350p
HA13412	600p
HA13432	400p
HA17524	250p
ICL7106	650p
ICL7660	240p
KA2102	150p
KA2130	150p
KA2206	150p
KA2209	125p
KA2210	230p
KA2212	80p
KA2213	130p
KA2214	150p
KA2261	100p
KA2263	100p
KA2264	100p
KA2284	100p
KA2401	150p
KA2412	350p
KA2912	125p
KA2914A	300p
LA1130	240p
LA1150	150p
LA1185	150p
LA1201	75p
LA1210	140p
LA1222	80p
LA1230	130p
LA1364	200p
LA1365	120p
LA1368	220p
LA1385	170p
LA2000	150p
LA2101	270p
LA2200	190p
LA3160	280p
LA3210	65p
LA3300	140p
LA3301	110p
LA3361	100p
LA3375	300p
LA4030	180p
LA4031	140p
LA4032	140p
LA4051	160p
LA4100	85p
LA4101	80p
LA4102	100p

Part	Price
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LA4120	270p
LA4140	60p
LA4160	100p
LA4182	180p
LA4190	300p
LA4192	140p
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LA4270	300p
LA4420	140p
LA4422	130p
LA4430	130p
LA4440	150p
LA4445	150p
LA4460	120p
LA4461	120p
LA4500	200p
LA4505	220p
LA4508	200p
LA4510	200p
LA4520	170p
LA4550	200p
LA4555	120p
LA4570	130p
LA5112	200p
LA5523	150p
LA5527	150p
LA5700	300p
LA7011	220p
LA7033	400p
LA7042	280p
LA7046	300p
LA7224	150p
LA7505	250p
LA7507	250p
LA7520	200p
LA7620	500p
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LC7132	400p
LC7137	450p
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LF355	60p
LF357	70p
LF398	300p
LM301	26p
LM311	35p
LM319	165p
LM324	30p
LM335Z	120p
LM339	35p
LM348	50p
LM358	45p
LM380	80p
LM381	150p
LM382	130p
LM386	60p
LM387	100p
LM393	45p
LM431	50p
LM710	45p
LM723	40p
LM741DIL	18p
LM741MET	45p
LM747	55p
LM1889	300p
LM1894N	200p
LM3900	40p
LM3909	100p
LM3914	160p
LM3915	160p
LM3916	270p
L200	200p
M491BB1	500p
M494B1	700p
M50115P	320p
M50117P	500p
M50119P	525p
M50784	300p
M50786	500p
M50790	600p
M51161	300p
M51381P	200p
M51387P	800p
M51544	150p
M51848	150p
M54523P	200p
M54563P	200p
M58484	500p
M51516	260p
M51518	200p
MB3712	140p
MB3713	130p
MB3714	270p
MB3715	250p
MB3722	280p
MB3730	160p
MB3731	220p
MB3756	160p
MB3759	200p
MB8719	360p
MC1455	45p
MC1496	65p
MC3401	45p
NE555	20p
NE556	40p
NE558	80p
NE565	110p

CIRCLE NO. 117 ON REPLY CARD

60A half bridge draws milliampere quiescent

Modules and other paralleled mos-gated power transistors often present difficulties in gate-drive circuit design.

Most mos gate drivers provide large peak output currents, acceptable for most applications. However, when driving large loads of many paralleled devices, excess power dissipation may become an issue when switching above a few tens of kilohertz. International rectifiers design tips dt 92-2 outlines a way of alleviating this problem by using a current buffer.

Figure 1 shows a typical circuit for a high input impedance power buffer. It delivers 8A peak output but draws only negligible quiescent current. Transistors $Q_{1,2}$ are low current drivers for $Q_{3,4}$ which can be sized to suit peak output current requirements.

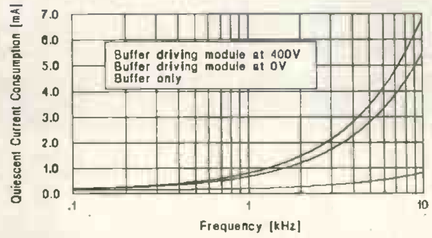
When the input changes state the 100Ω resistor limits the resulting current of $Q_{1,2}$. In its new state, the driver transistor discharges the gate capacitance of the conducting output transistor, forcing it into off-state.

The gate of the other output transistor charges through the resistor. Turn-on is delayed by the *RC* time constant formed by the resistor and the input capacitance of the output transistor.

The configuration of **Fig. 2** employs two power buffers in conjunction with a *IR2110* half-bridge driver, which combine to create a high-current half-bridge circuit.

Each buffer receives its drive signal from the *IR2110*. They in turn drive an insulated-gate bipolar transistor module with a total gate charge, Q_G, of typically 600nC. The modules switch an inductive load current of 60A. It is possible to use lower voltage power mosfets ie 60V. However, the large reduction in $R_{DS(on)}$ causes a great deal of noise and ringing in the circuit due to a rise in large peak currents.

International Rectifier, *Hurst green, Oxted, Surrey RH8 9BB, UK.*
Tel 44 883 713 215, fax 716 093.



Quiescent current of the 2110 rises with increasing frequency, but even at 10kHz, the figure is still under 7mA.

Fig. 1. This high input impedance current buffer delivers 8A peak output yet draws negligible quiescent current.

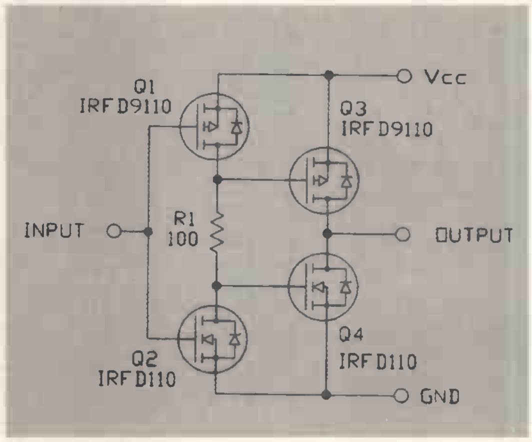
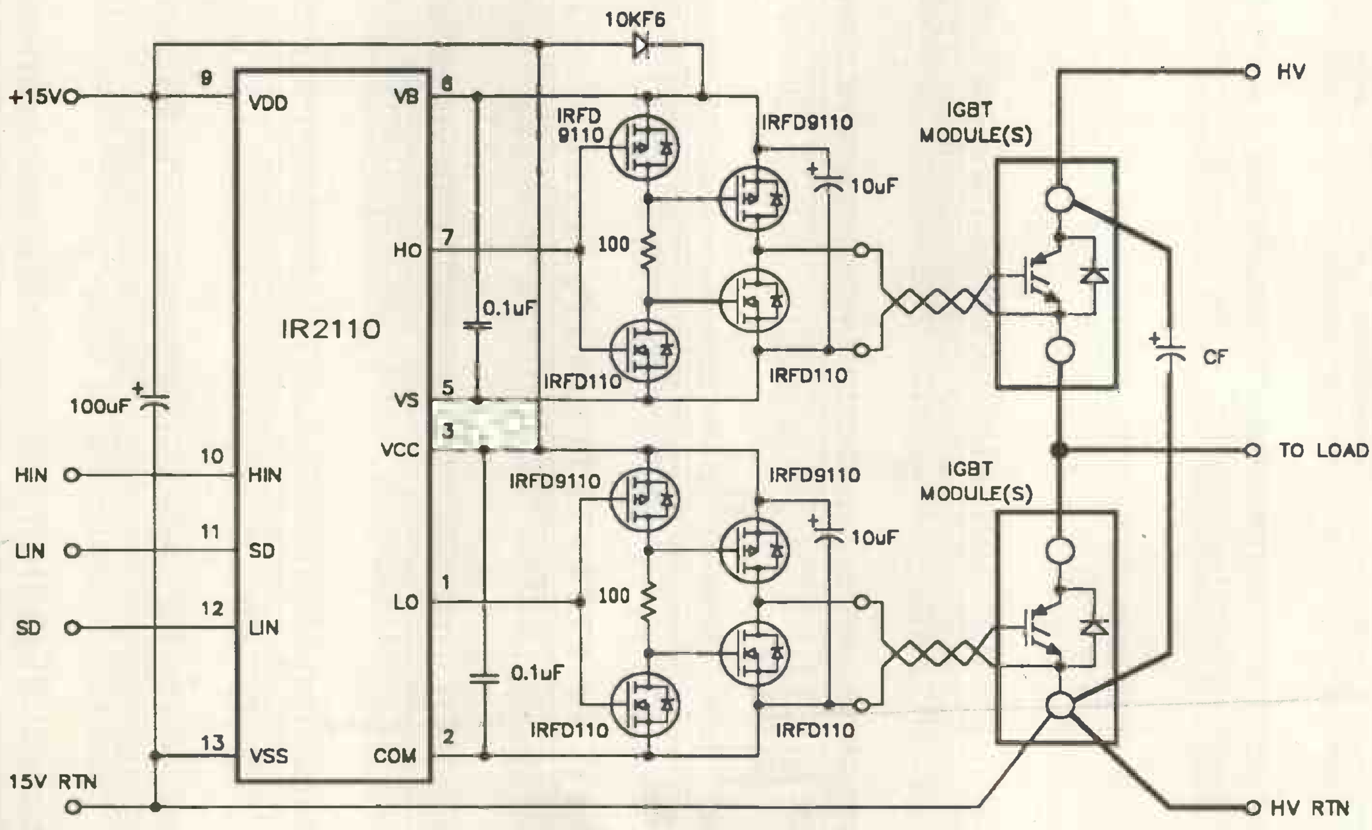


Fig. 2. Two power buffers with an IR2110 driver combine to create a high-current half-bridge power driver for 60A IGBT modules.



Autoshutdown reduces RS232 standby current to 1μA

Maxim's eighth edition of the Interface *Analogue Design Guide* outlines a new invention that automatically reduces standby power of an RS232 interface to 1μA.

Reducing supply current is a critical factor for extending battery life in any hand held device. Ideally any idle RS232 IC should draw no supply current without degrading performance or increasing cost. With this new invention, the IC draws only 1μA, providing the device is not connected to an operating RS232 system.

Called Autoshutdown the scheme involves monitoring the RS232 receiver inputs. If no valid RS232 level is present, the IC automatically turns the device on/off, rather than relying on independent software commands to perform the shut-down.

This device is claimed to save 1000 times the supply current relative to other RS232 devices. It is said to be suitable for any hand held system – regardless of the complexity of software.

The RS232 IC is available in four versions. Each has different characteristics suited to different applications. These include varying data rates, a choice of operating supply ranges and a selection of transmitters/receiver permutations.

Maxim Integrated Products(UK) Ltd.
Unit 3, Theale Technology Centre, Station Rd Theale, Berkshire RG7 4XX, Tel 01734 303388, fax 01734 305577.

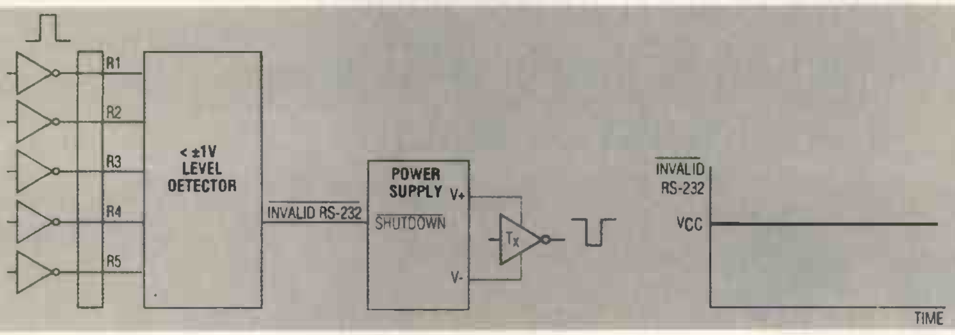


Fig. 1. RS-232 inputs are monitored to determine if they are connected to a transmitter. Inputs less than ±1V for more than 10μs are considered invalid.

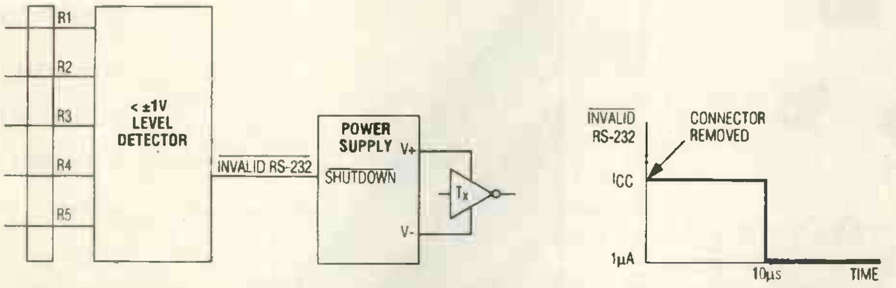


Fig. 2. Valid/invalid RS-232 input detector signal is sent to the power-supply circuitry. Some 10μs after valid inputs are removed, the power supply is shut down, reducing its current to 1μA.

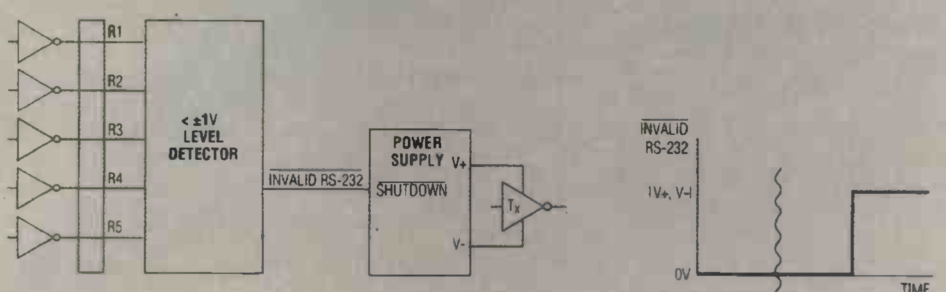


Fig. 3. A valid RS-232 signal is detected and the power supply is activated allowing transmission and reception of data.

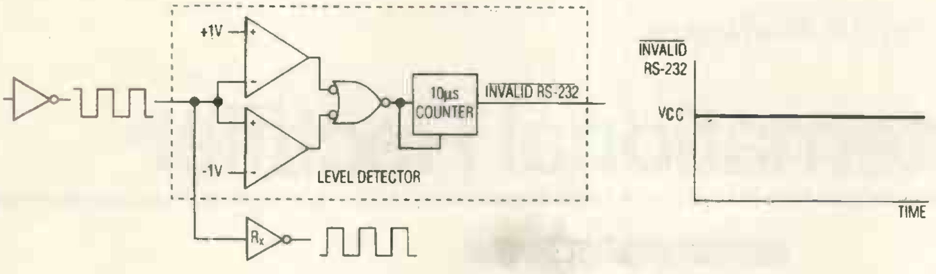


Fig. 4. While data is being received, the device does not enter shut down, because input levels less than ±1V are not present for more than 10μs.

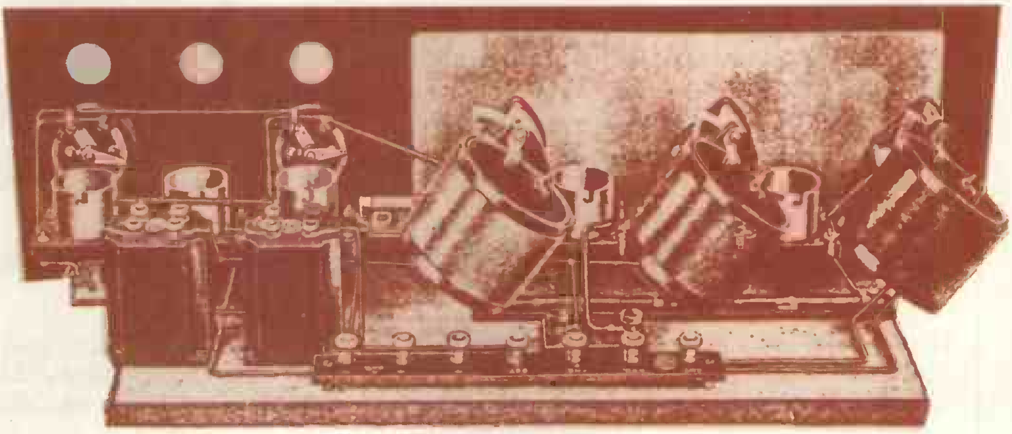


Fig. 1. Rear View of the Fada Neutrodyne trf radio showing its inclined coil arrangement. In conjunction with Hazeltine neutralisation circuits, this physical layout enabled stable rf amplification over the whole broadcast band. Prior to practical and cost-effective super-heterodyne sets, the Neutrodyne represented state-of-the-art technology. It flourished during the 1923-26 time frame.

A new slant on an old angle

Irving Gottlieb has been looking at the Neutrodyne – a receiver that achieved high gain without suffering from oscillation due to stray coil coupling. "Why is this simple solution not in use today?" he asks.

Oscillation caused by stray coupling between tuned circuits is a common problem in multi-stage rf and if amplifiers that need to be constructed in a small space.

Toroidal inductors help reduce the tendency towards oscillation. Alternatively, cylindrical-shaped inductors can be mounted so that they are mutually perpendicular to one another. A third approach stems from the Neutrodyne technique used in early battery radios in vacuum-tube tuned radio-frequency, trf, circuits.

This method arranges the coils at a slant with respect to the horizontal. The 'magic' angle used was 54.7° – the tangent of which happens to be the square-root of two. Electromagnetic coupling was surprisingly scarce between any two of the coils, the layout of which is shown in **Fig. 1**.

You might be tempted to analyse the existence of this coupling null mathematically, but calculations turn out to be extremely complex. Subsequently, best results accrue from empirical work.

The angle is not sacred. Variations of plus or minus several degrees produce similar results. The reason for this is that the angle is a function of wire size, winding length, coil shape and coil spacing. Other variables tend to creep in with regard to proximity effects.

However, the null is attainable over a wide range of dimensions and circumstances. A useful aspect of the phenomenon is that it is not frequency-sensitive. In old radio sets, near-zero couplings held good over the entire broadcast band.

A straightforward way to implement this technique is to use coils whose diameter and winding length are about the same. This coil configuration also tends to yield optimum Q. Spacing between coils of about-one coil-radius appears to work best. Closer spacing can be accommodated, but the null then becomes more critical to adjust. This is probably due to capacitive coupling.

Electromagnetic isolation provided by this strange scheme does not tie in with our everyday experience of tuned circuits. You might expect strong coupling, for instance somewhere between that due to axial alignment and that caused by perpendicular orientation of the coils. However, with an rf generator, oscilloscope, and a pair of resonant coils, you can easily observe that energy transfer neatly nulls when the coils are positioned approximately as prescribed.

Surely, this is a useful phenomenon – one that has probably been overlooked in modern electronics because of the many more exciting advances that have captured our interests. After researching many radio and engineering tests, even contemporary ones of

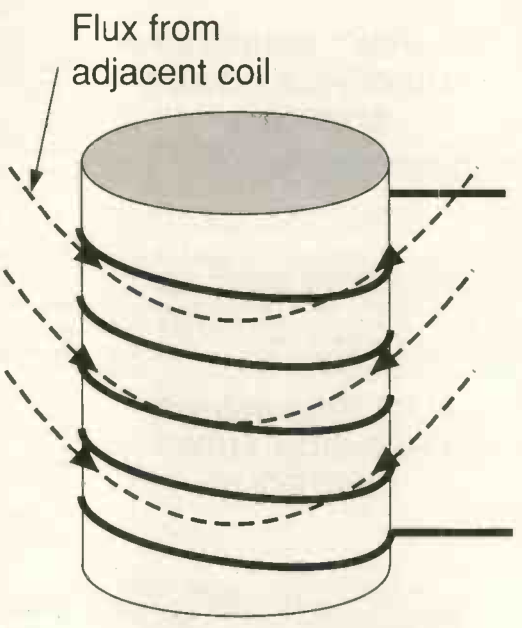


Fig. 2. Magnetic flux lines threading through a coil 'slanted' for zero-coupling. Under the null conditions, the coil-conductors are cut symmetrically by both downward and upward-sloping flux lines. A net cancellation of induced voltage takes place so that there is no effective electromagnetic induction. Zero-coupling achieved in this way prevented unwanted feedback in the Neutrodyne radio receiver.

the Neutrodyne, I met with frustration and disappointment. I could find no explanation of this cause and effect relationship. In seeking an analysis from engineers, most of them viewed the situation as a paradox. Here, however, appears to be a feasible solution.

In **Fig. 2**, you can see lines of magnetic flux threading through a coil. The flux emanates from an adjacent coil and it is assumed that the 'magic angle' exists between the coils.

Note the symmetry of the downward and upward-sloping flux lines. This certainly implies electromagnetically induced emfs in the coil conductors. However, because of the alluded symmetry, these emfs cancel. This is tantamount to zero coupling between the coils.

If the angle is different from the 'magic' one, either the upward or downward slope lines will predominate and a net emf will then manifest. Bear in mind that it is the component of the magnetic lines that 'cut' the coil conductors at right angles that counts. If you mentally rotate the coil with respect to the magnetic lines, the notion of the 'magic' angle is driven home.

Professor Hazeltine was a brilliant mathematician. It appears that he deduced this invention from theoretical considerations. For our purposes, the descriptive account tendered here should suffice for useful results.

From a number of experiments, I would suggest mounting the coils in such a way as to allow a few degrees of angular adjustment. You can then build a high-gain amplifier channel in a small space and carefully adjust the coil slants so as to optimise stability. In doing so, you can compensate for various stray feedback paths since the coil adjustments allow small amounts of negative feedback. ■

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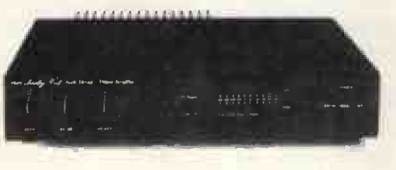

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CIRCLE NO. 122 ON REPLY CARD

Steve Winder presents a new approach to providing a balanced amplifier output for twisted-pair transmission lines. Using the supply pins of an op-amp as a combined supply and line-connection point, this scheme eliminates the need for a line-coupling transformer at the remote end.

A new balanced view

Readings from sensors in remote locations are often sent to the base station via an amplifier feeding a twisted pair. The amplifier can be powered locally by battery or mains supply. Most often, though, there is a dc feed from the base station.

If only one cable pair is available, the dc feed must use the same pair as the signal. Line transmission requires a balanced output and, if local power is available, there are two methods of providing it,

- using two amplifiers connected to the same source. One amplifier is inverting and the other is non-inverting. Any signal applied to the input will produce two outputs which are anti-phase – and balanced – and so can be connected to the two wires of the twisted pair.

- driving a transformer from an amplifier's output. The secondary winding of the transformer will be balanced and suitable for connection to the transmission line.

When local power is unavailable the second configuration can be used, but using a transformer with split secondary windings and as shown in **Fig. 1**. These windings are capacitively coupled to allow the ac signal to pass through both of them in series.

Direct-current feed from the base station travels along the pair and can be taken from across the coupling capacitor to the amplifier's power connections. Unfortunately the line coupling transformer is bulky and is difficult to design because of the dc flowing through its windings.

I have found an alternative to using the transformer is to apply the line directly across the amplifier's power supply pins, as shown in **Fig. 2**. At the base station, dc power is fed into the line using a split primary transformer. The two halves of the primary winding are capacitively coupled so that ac signals pass through the transformer.

A dc supply for the amplifier is fed through the primary windings and down the twisted pair. At the sensor, the twisted pair is connected across the amplifier power supply pins. The amplifier output is loaded by a resistor to produce a change in current flow from the supply when signals are applied at the input.

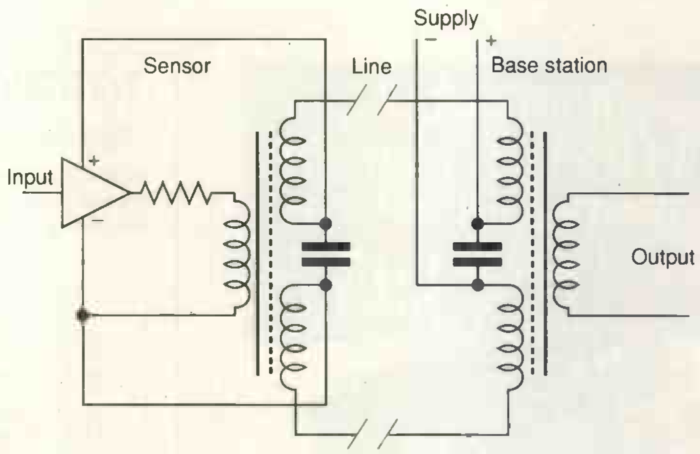


Fig. 1. Impedance analysis of transformer-coupled balanced i/o system. Windings are capacitively coupled to allow the ac signal to [ass through them in series.

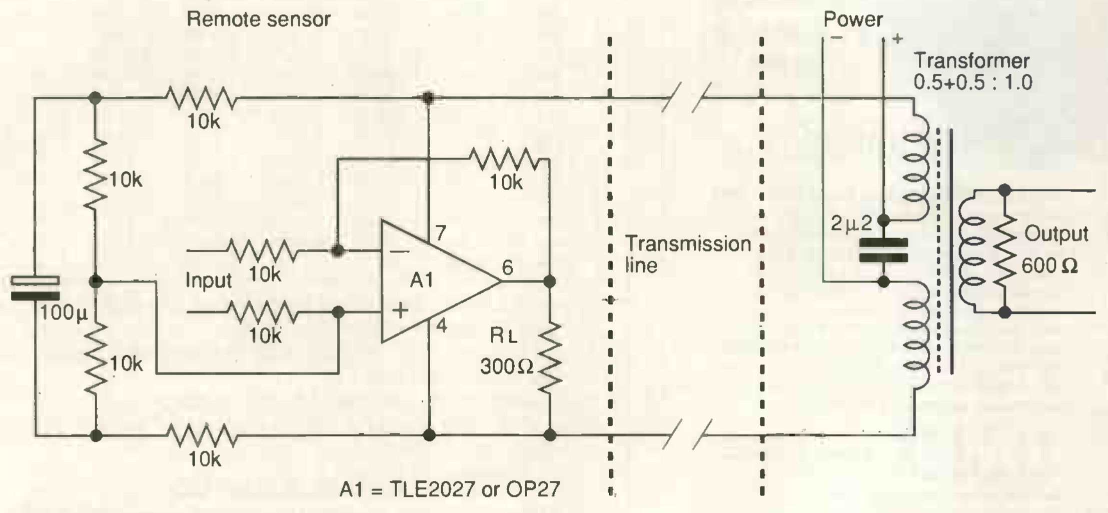


Fig. 2. In this alternative to the conventional transformer-coupled balanced system, the line is applied directly across the amplifier's power supply pins.

To make the impedance of the remote sensor equal to 600Ω it is necessary to use a 300Ω load at the amplifier. The reason for the load resistor value being half that of the line impedance follows.

Consider an ac signal applied to the transformer output. As the potential of the positive supply rail rises, the negative rail will fall, relative to the mid-rail voltage. The ac voltage from the negative rail to the mid-point will be half the total voltage change. This same voltage appears across the load since it is connected between the negative rail and the output of the amplifier which is at mid-rail potential. Thus only half the ac voltage appears across the load, so only half the current flows through it and the effective impedance of the amplifier seen from the transformer is doubled. This is illustrated in **Fig. 3**.

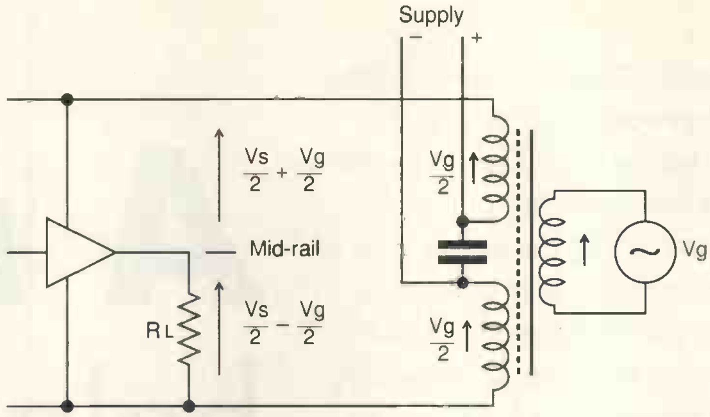


Fig. 3. Analysis shows that only half the ac voltage appears across the load so only half the current flows through it. As a result, effective impedance of the amplifier seen from the transformer is doubled.

This scheme requires a decoupled mid-rail supply to be generated locally, but this is simple to achieve using a few resistors and a capacitor; as shown in **Fig. 4**.

Thévenin's theorem can be used to analyse the circuit. Potential at the centre of the resistor chain is $V/2$. The source impedance is approximately equal to R, relative to the power supply rails. This is because the power rails are much lower in impedance than R – actually about 300Ω – and so signals applied to the centre of the resistor chain have two parallel paths to the 0V rail, both $2R$.

The decoupling capacitor does not affect the impedance because an equal ac potential appears at each terminal. In theory, signals on the power supply rails are balanced and the centre of the resistor chain should have no ac component present. The decoupling capacitor should not be needed. In practice tolerances in the resistor values result in small ac signals reaching the mid-point unless a decoupling capacitor is present. ■

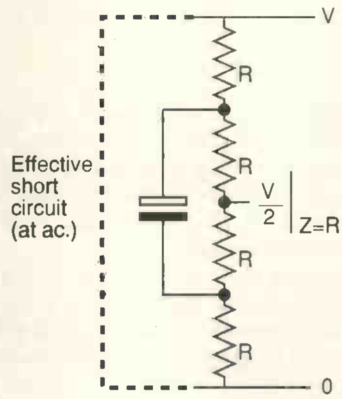


Fig. 4. Achieving a local decoupled mid-supply rail is easy, using a few resistors and a capacitor.

Square law rules in AUDIO POWER

To the best of Ian Hegglun's knowledge, the difference of two squares concept has never been used in audio power amplifiers, but as this work shows, there are significant linearity benefits to reap.

Michael Williams' article[1] shows how the difference of two squares – D2S – produces a linear output from a pair of fets, forming the basis for a perfect linear amplifier. This approach has never been intentionally applied to class AB amplifiers to reduce distortion. The reason is probably the inherent difficulty in obtaining conjugate gain characteristics in the crossover region to prevent crossover distortion[2,3].

Newly developed circuit techniques could solve this problem, and put the square-law to work in high power audio amplifiers. Experimental results demonstrate the effectiveness of these techniques, but first a look at the underlying theory.

Crossover distortion in class AB

Class-AB is most widely used due to efficiency and lower cost relative to class-A, but class-AB generates more distortion than class-A. Distortion from class-AB is mainly crossover related and cannot be eliminated by trimming. Negative feedback has difficulty reducing crossover distortion in the high audio range, where there is generally less feedback available for distortion reduction[4].

Our ears are more sensitive to frequencies in the 1-5kHz range, so crossover distortion is probably a more noticeable type of distortion. It is difficult to design out, and not easy to reduce using negative feedback.

The crossover distortion problem of class-AB power amplifiers is essentially that each of the two output devices must operate in two different modes. Firstly, each device must have constant gain at high currents, but secondly they must have a variable gain in the crossover region where both devices contribute to output current, **Fig. 1**. The ideal transfer function for no distortion is a straight line, Fig. **1a**. Gain is represented by the slope of the line which is constant, Fig. **1b**. Both devices conduct in the crossover region between $-V_1$ and $+V_1$. The gain of each device must sum to a constant value in the crossover region and the total gain must also match the gain outside the crossover region.

With symmetrical components, the gain of each device when V_{in} is zero must be exactly 50% for a sum of 100%. These requirements give a family of possible symmetrical gain functions that result in zero crossover distortion. A constant rate of change of gain, Fig. 1b, gives the square-law *V-I* transfer curve Fig. **1c**. This can be found from the gain function by integrating upwards from $-V_1$ for the positive conducting device and down from V_1 for the other.

An alternative gain function which satisfies the 50% gain requirement and is symmetrical about V_{in}=0 is shown in Fig. **1d**. At low currents, fets show exponential deviation from square-law[5], resulting in a gain curve that is initially exponential. This gives a rounded gain function at low current, Fig. 1d. This suggests it may not be necessary for a fet to show perfect square-law characteristics at low currents to give perfect linearity, provided that the gain curve can be made symmetrical. This should be possible by altering the shape of the top end transition, ie below $\pm V_1$.

Classical bipolar and fet class AB stages do not meet these requirements. Figure **1e** shows significant gain non-linearity[6] in and near the crossover region. Gain is 32 with a variation of –4, representing a 13% change when biased for minimum distortion.

Gain error results from one transistor turning off before the other has reached constant gain. Resistors in the emitters cause the gain to flatten at high currents, but the transition occurs over far too wide a range. Figure **1f** is the *V-I* transfer function for ±1V input, giving ±32V output and ±4A peak into 8Ω.

The difference between the line having average gain, i.e. about 31, and the output line results in the distortion component. The error voltage is about 500mV pk-pk, or 200mV rms, with total harmonic distortion of about 1%. If this stage were reconfigured as a unity-gain follower, the action of local feedback would reduce total harmonic distortion to 0.03%.

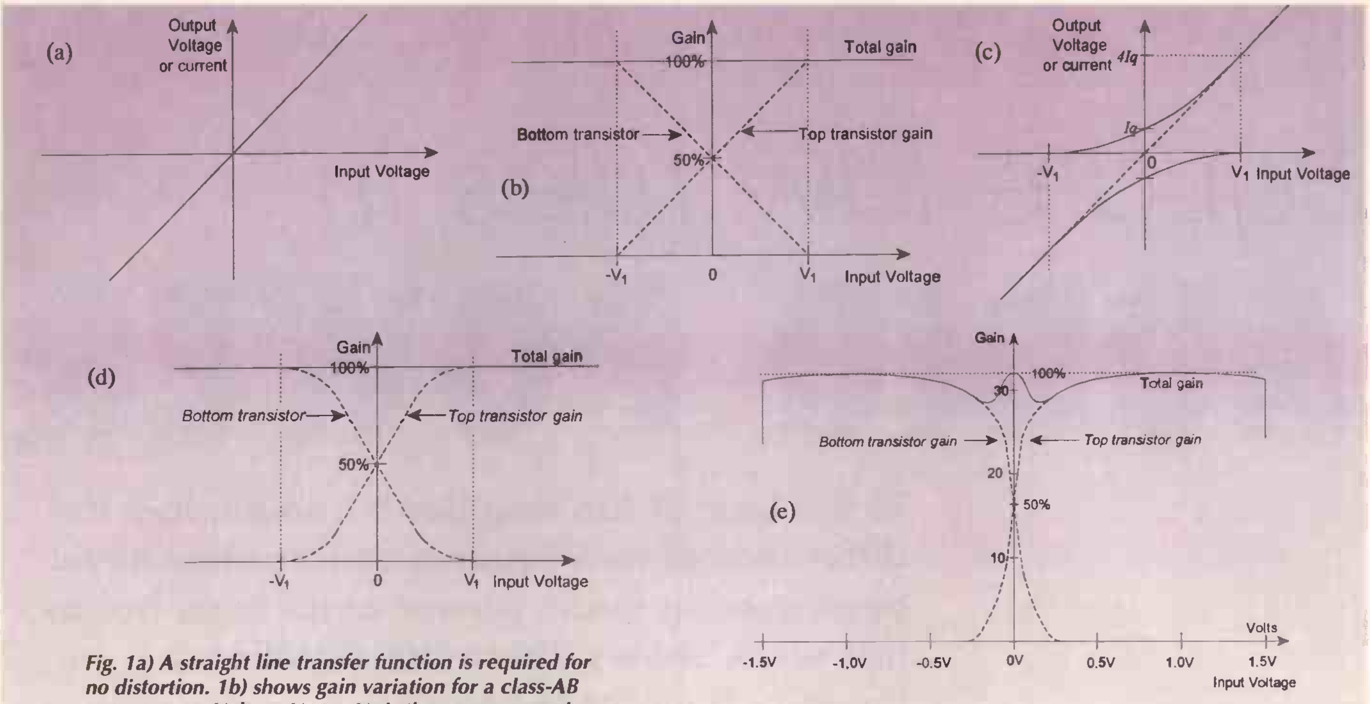
More feedback

Negative feedback usually reduces crossover distortion. Due to increasing phase change with frequency, a limit must be put on the amount of negative feedback[4]. In particular, the gain of the feedback loop plus the amplifier must be under unity at the frequency where 180° phase shift occurs. This prevents oscillation and likely destruction of the output transistors.

The 180° phase shift represents a complete phase reversal, turning negative feedback into positive feedback. If the gain ≥1 at the frequency where 180° shift occurs, the circuit will oscillate. Ideally the gain should fall below 0.7 at the 180° point to give a well-damped response to a square wave.

Load impedance variations have an effect on the loop gain-phase relationship. Capacitive loading from speaker leads and speakers adds phase shift to the output and therefore to the feedback signal[4]. Most output stages are unity-gain follower types with 100% local feedback. These are more sensitive to loading than output stages that have less than 100% feedback and have a gain above unity.

An appropriately designed Zobel network usually overcomes this problem. Generally a



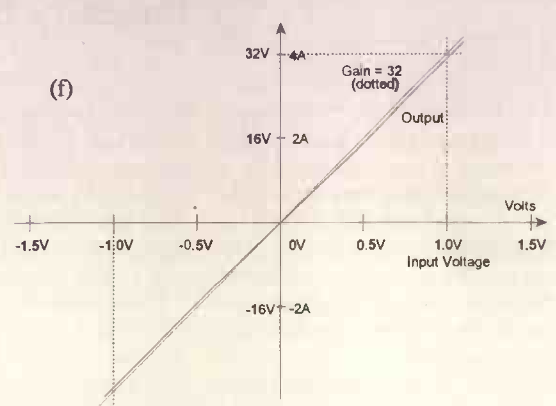


Fig. 1a) A straight line transfer function is required for no distortion. 1b) shows gain variation for a class-AB output stage. Voltage V_1 to $-V_1$ is the crossover region. Individual gains in the crossover region need to sum to a constant value.
In 1c), the transfer functions required for Fig.1b are square-laws in the crossover region and linear beyond. 1d) shows an alternative gain function that also gives no crossover distortion. Both curves must have odd symmetry about the y-axis.
In 1e), gain linearity of a bipolar common emitter output stage is shown. Assymetry makes it impossible to eliminate distortion, based on Self's Fig. 8 ref. 6. Transfer function for the bipolar common emitter output stage Fig.1e is shown in 1f). Difference between the average gain of 31 and the output is the distortion component.

conservative amount of global feedback is used to remove any possibility of oscillation.

Using fets as square-law devices, it should be possible to reduce the amounts of feedback required to a level that eliminates complications caused by loading – making amplifier design easier.

The ideal circuit should also be highly efficient – preferably as high as class AB – to minimise cost. Any distortion should consist mainly of a few low-order harmonics rather than the high variety[9].

Our ears are more sensitive to high-order odd harmonics produced by crossover distortion – particularly if they lie in the sensitive hearing region. Ivor Brown suggests the multiplicity of high order harmonics from crossover distortion reduces spatial definition[8].

Differencing two squares

Michael William's article[1] explains the principle of differencing two squares – D2S – also known as 'Curvelinear class-A'. By definition, D2S is class-A since both devices are always conducting. However, the mode of operation shown in Fig. 1c is class-AB – a different class from D2S which I call 'Square-law class-AB'. Only one device conducts when the input swing exceeds $\pm V_1$.

As Williams points out, D2S has the advantage of a lower quiescent current than class-A per output watt. Heat dissipated at idle P_q, is $\frac{1}{2}I_{pk}V_{cc}$, since the quiescent current is set at a quarter of the peak output current ($I_q=I_{pk}/4$).

For split supply rails of $\pm V_{cc}$, quiescent power dissipation P_q is $2V_{cc}I_q$, which is $\frac{1}{2}I_{pk}V_{cc}$. Neglecting saturation and ripple voltages, this is the same as the output power rating.

Saturation and ripple voltages, say 2V for saturation and $2V_{rms}$ ripple ($6V_{p\text{-}p}$), cause dissipation to rise by 10%. Both conventional class-A and D2S require this same margin which means practical class-A push-pull amplifiers dissipate twice the power of the D2S amplifier per output watt. For class-AB, dissipation peaks at half full power, dissipating typically the same amount as heat. As a result, maximum dissipation is $\frac{1}{2}$ of maximum output power, so D2S dissipates twice the power of class-AB.

The maximum possible sinewave efficiency for D2S, as detailed in the appendix, is 75%, compared to 50% for push-pull class-A and 78.5% for class-B. Since the efficiency of D2S and class-AB are almost the same, their power supply rating is likewise. As a result, D2S offers a substantial cost advantage over other types of class-A due to its high efficiency – effectively the same as class-B. Requiring only a larger heatsink D2S is slightly more expensive than class-AB.

Operating in class-A using D2S, rather than class-AB, crossover distortion can be avoided completely at little extra cost. Distortion components are mainly second and third harmonics. Due to component mismatch most of the second harmonic can be trimmed by equalising the gain difference. Third harmonics can be compensated by gain drop in the fet. Trimming these errors can be considered a form of *feed-forward* error correction, relying on the stability of the other parameters to maintain linearity after set-up.

Most amplifiers already require the setting of one preset at manufacture, so another should not be a serious disadvantage.

Implementing the concept

Douglas Self[6] explored a power-fet square-law circuit (Self's Fig. 2) but found the range for the square-law only extended over a disappointing 80mA range of output current. This circuit was class-AB with only one device conducting at high currents.

Examining the *V-I* transfer curves of Self's Fig. 10, you can see that considerable local feedback is applied to the fets. About 1V appears across the 0.22Ω source resistors at 5A with 1.5V input. This amount of feedback kills the square-law relationship – even at low currents. Reducing or eliminating these resistors increases the useful square-law current range.

The design example described in the panel shows that *IRF540/9540* power fets could achieve class-A power levels of 100W with distortion as low as 0.0005%, without trimming. This appears possible even with a 12% fet gain drop at peaks, and a 16% mismatch. It suggests that ultra low distortion D2S amplifiers are not only possible, but cheaper than other class-A amplifiers.

Class AB square-law circuits

The circuit of **Fig. 2** was constructed to evaluate power fets for class-AB. It is similar to Self's Fig. 2 evaluation circuit[6], minus source resistors.

Driver transistors $Tr_{3,4}$ provide level shifting for the fets as well as biasing and voltage gain. Unlike conventional class-AB driver circuits the emitters are not coupled. This gives a wider crossover region – wider than the fets' range $\pm V_1$. Effectively, the power fets are open loop, ie they have no source resistors, apart from a small amount of voltage feedback used to trim the higher gain half for symmetry.

Figure 3 shows triangle wave input and output voltages. Supply is reduced to ±22V so saturation can be seen. Open-loop linearity is maintained up to within a few volts of saturation. Traces are offset by 0.47V to aid trimming. Vertical differences represent the output error voltage.

Deviation of about $0.2V_{pp}$ appears at the ends, covering about $^1/_4$ of the time. Since total harmonic distortion is the ratio of rms error voltage to rms output voltage, the rms error voltage can be calculated using,

$$V_{RMS} = \frac{V_{pp}}{2\sqrt{2}}\sqrt{\frac{t}{T}}$$

where *t/T* is the duty cycle. In this case error voltage is 35mV rms for $12V_{rms}$ output voltage, giving 0.3% thd open loop. Open loop measurements are shown in **Table 1**.

Table 1. Open-loop performance of amplifer based on difference of two squares principle. Phase shift was 180° with 8Ω load at 10kHz.

Load	bias	thd	gain
8Ω	250mA	0.3%	20
4Ω	500mA	0.5%	15
8Ω	500mA	0.5%	30

Fets used here have a 7A/140V rating and R_{DSon} of 1Ω. Measurement showed their gate thresholds were very low and quiescent voltage across $R_{7,8}$ was only 1.1V and –0.75V for a quiescent current of 250mA. These fets are still capable of delivering high currents efficiently since gate voltages in this circuit can swing up to $^2/_3$ of the supply voltage, limited

Efficiency in D2S class-A

Equations in this panel describe efficiency in D2S class-A using two square-laws.

With a sinewave input each fet has a current waveform given by,

$$I(x) = \frac{I_{pk}}{4}(\sin x + 1)^2$$

$$I_{ave} = \frac{1}{\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{I_{pk}}{4}(\sin x + 1)^2\,dx$$

$$\therefore I_{ave} = \frac{3I_{pk}}{8}$$

for each half,

$$P_{in} = 2I_{ave}V_{cc} = \frac{3}{4}I_{pk}V_{cc}$$

and,

$$P_{out} = \frac{V_{pk}I_{pk}}{2} = \frac{(V_{cc}-V_{sat})I_{pk}}{2}$$

$$\therefore \eta = \frac{P_{out}}{P_{in}} = \frac{3}{4}I_{pk}(1-\frac{V_{sat}}{V_{cc}})$$

Maximum possible sinewave efficiency is 75% with V_{sat} at 0. When V_{sat} is 5V and V_{cc} is 35V, efficiency is 64%.

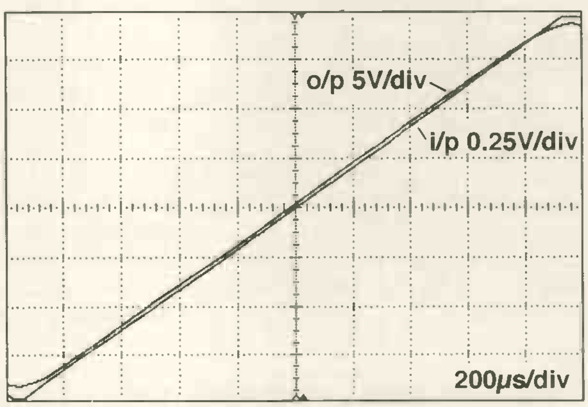


Fig. 3. Output of circuit of Fig. 2 with a triangle wave input shown for comparison.

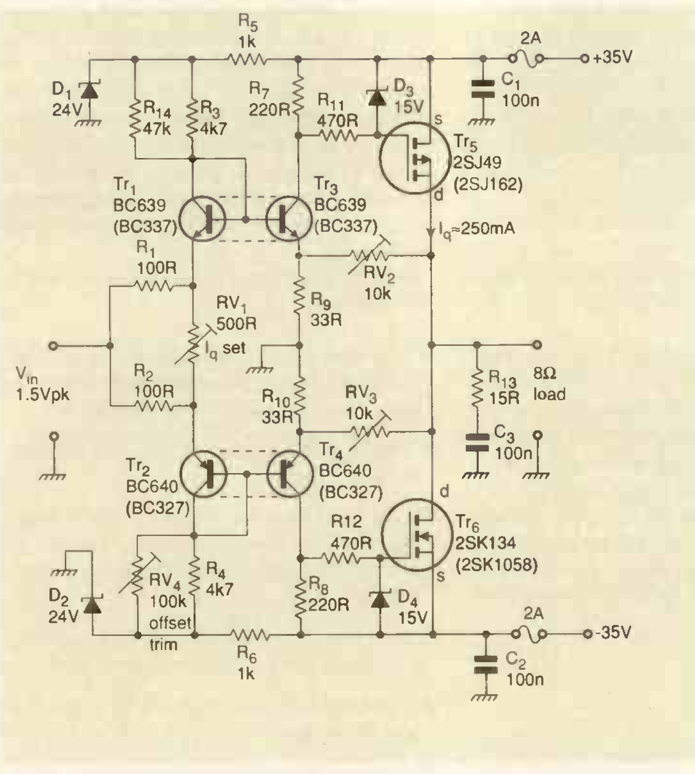


Fig. 2. Class AB output stage with power fets operating as approximate square-law devices in the crossover region with correction provided by increasing gain of the driver transistors.

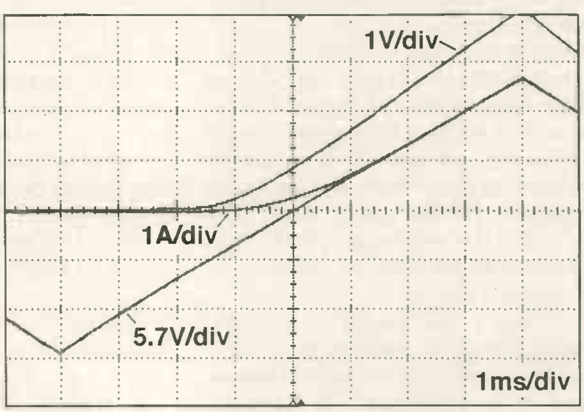


Fig. 4. Curves for Fig. 2 with output voltage, Tr_3 current and gate voltage show square-law region, linear region and non-linear gain of driver used to compensate for fet gain drop.

A 100W D2S fet amplifier

For 100W continuous into 8Ω, output swing is ±40V peak at ±5A peak. For D2S, quiescent current must be set at $^1/_4 I_{pk}$, or 1.25A.

Peak input voltage V_1 can be calculated for a specified distortion level as follows. Velocity saturation[5] causes a reduction in output current at high current, causing gain compression.

Assuming matched fets, there is no second harmonic, but there is mostly third harmonic distortion for which,

$$D_3 = \frac{\delta^+ + \delta^-}{24}$$

(eq. 12 of ref. 11).
With velocity saturation,

$$I_D(\theta) = \frac{\beta(V_G - V_T)^2}{2[1+\theta(V_G - V_T)]}$$

Taking the ratio of current with saturation velocity to the ideal current gives

$$\frac{I_D(\theta)}{I_{D(ideal)}} \cong 1 - \theta(V_G - V_T).$$

This shows the gain compression factor $\Delta \cong \theta(V_G - V_T)$. For, say, 1% of third-harmonic at full power using the equation for D_3, with $\delta^+\delta^+ = \delta^- = \Delta G$, gives $\Delta G = 0.12$. Using a typical value for θ of $0.1V^{-1}$, peak gate rise $V_G - V_T$ is 1V. This means that V_{in} is $\pm 0.5V_{pk}$.

With a 3V threshold voltage, the fets would need to be biased[5] at 4V, reducing by 6mV/°C. Since peak current is 5A with a gate rise of 1V, the fet requires a gain of 5A/V. The minimum value of β, calculated from $g_{fs} = \beta(V_G - V_T)$, is $5A/V^2$.

For an *IRF540*, β can be found from the data sheet *V-I* transfer curves by plotting $\sqrt{I_D}$ against V_G using,

$$slope = \sqrt{\frac{\beta}{2}}.$$

This yields a β of $11A/V^2$ with V_T at 3V for both the *IRF540* and *IRF640*.

Their complements, the *IRF9540* and *9640*, typically have betas that are 25% lower. This means they are suitable for a 100W D2S class-A amplifier with 1% thd, open loop.

Fet gain mismatch causes the gains at each end to be different, giving mainly second harmonic distortion, calculated from,

$$D_2 = \frac{\delta^+ - \delta^-}{8}$$

1

(eq. 12a of ref. 11). A mismatch of 8% adds 1% second harmonic distortion. Total open loop distortion is 1.4%,

$$D_T = \sqrt{D_2^{\,2} + D_3^{\,2}}$$

Open-loop voltage gain is calculated from $A_V = G_{fs}R_L = 80$ where the overall gain G_{fs} is the same as the g_{fs} calculated above at the end points. Distortion of this output stage can be compared to other unity gain output stages using the relationship,

$$D = \frac{D_{OL}}{1 + \beta A_{OL}}$$

where β is 1 for 100% feedback.

With a gain of 80 and 1.4% open loop distortion, the equivalent unity gain distortion is 0.02%. Similarly, a gain drop of 20% with a gain of 80 is equivalent to a drop of 0.3% at unity gain. Douglas Self's class-A output stage (Fig. 3 of ref. 10) shows a gain drop of 0.3% at 70% output swing at 30W, giving 0.0012% thd at 20kHz with 30dB global-feedback factor, also at 20kHz.

by zeners. For a low saturation voltage of say 3V, the fets would be restricted to 3A (50W average) but linearity is still good up to 5A allowing 100W average into 8Ω, making them cost effective.

To measure fet current, a 0.1Ω sensing resistor was placed in the supply rail, with no noticeable effect on linearity. **Figure 4** shows fet current with output voltage using a triangle wave input after trimming for best linearity. The output voltage is vernier scaled until this curve merges with the current trace. This allows square law and linear regions to be clearly seen in the top transistor similar to the curves shown in Fig. 1c.

Gate voltage is also displayed at 1V/div. The current waveform appears to be a square-law within the crossover region and outside the gain it is reasonably linear. The square-law crossover region covers an input swing of ±0.8V. The quiescent current of 220mA was stable with temperature on a 1°C/W heatsink. Current at the end of crossover region is about 0.8A – four times I_q – indicating square-law operation.

Gain of the driver transistor can be measured from the gate voltage waveform. It doubles from $-V_1$ to $+V_1$. Increasing the gain of the driver transistors offsets the fet gain drop due to velocity saturation within the square-law region, resulting in a near ideal square-law relationship. At V_1 the fet has gone linear[5]. This demonstrates that the falling gain of fets is not an obstacle for the square-law principle.

Theory[5] shows gain falls by 50% at high currents. Using,

$$G_{fs} = \sqrt{2\beta I_D} - 3\theta I_D$$

the gain peaks at,

$$G_{fs} = \frac{\beta}{60}$$

where,

$$I_D = \frac{\beta}{18\theta^2}.$$

This is half the gain of the ideal fet where θ is 0 and velocity saturation does not occur. It is possible to calculate the beta required for a given amplifier, given θ of say 0.11, using $\beta = 18\theta^2 I_D$, where I_D is the output current at the inflection point (G_{fs} maxima, where the *V-I* plot curves backwards). Current I_D is therefore arbitrary. It simply depends on how much of the rated capacity of the fet is to be used.

A useful technique to find θ and β from data sheets that give the G_{fs} versus I_D curve, that shows a peak is,

$$\beta = \frac{2G_{pk}^{\,2}}{I_{pk}}$$

and,

$$\theta = \frac{G_{pk}}{3I_{pk}}$$

G_{pk} and I_{pk} are G_{fs} and I_D at the maxima.

Values of $R_{7,8}$ were altered to suit the amount of compensation required for a particular fet and operating current range. Increasing bias voltage gives less gain compensation for higher gate bias voltages of modern power fets. I expect equations can be found to calculate resistor values from β, θ, peak I_D, etc.

Interestingly, the slow gain change of bipolar class-AB circuits – the cause of crossover distortion – is advantageous in offsetting the slow gain change of the fets from square-law to linear. Modern op-amps with output swings of ±10V can be used to drive output stages if they have voltage gain. For example, the *OPA627*, although expensive, can give distortion figures as low as 0.0003%[12] with a gain of 3 and the *NE5534* can give almost as good performance[13] at lower cost. They can provide suitable slew rates, and more importantly, reduce component count. They are probably not more widely used in this type of application because the usual starting point in a design is with a voltage follower, unity gain, output stage.

Other advantages of using output stages with gain are:

- Improved output stage stability due to lower feedback factor. This makes it easier to ensure less than unity loop gain at 180°.
- Higher efficiency due to lower saturation voltage.
- Biasing current can be derived from a regulated/filtered supply, improving power supply rejection and its resulting effect on distortion.
- Slew rate required for the driving amplifier is reduced due to the output stage gain.
- Driver transistors only need to be rated at half the supply voltage.
- Output is a current source so current limiting can be performed by simply limiting input voltage swing using diodes.

Another square-law circuit

The circuit of **Fig. 5** uses *74HCU04* cmos inverters as drivers for the bipolar output transistors. In this arrangement ambient temperature variations need not affect linearity, whereas changes in load cannot.

C-mos inverters provide well matched complementary fets, readily available and cheap. When the six inverters in a *HCU04* are paralleled, 120mA can be safely handled, at which point the gain drops by 10%. This is sufficient to drive a bipolar power transistor for 5A output, given a beta of 50 at 5A.

For six *HCU04* inverters in parallel, fet parameters are β=50mA/V^2, V_T=0.8V and θ=0.12(V^{-1}). Matching of p and n beta values was within a few percent. Devices with the same date mark had almost identical betas, although the threshold voltages of p fets were typically 80mV higher than n fets for those tested.

The *HCU04* runs from 5V. Figure 5 uses a level shifter with one *HCU04* driving both sides to increase voltage swing.

Figure **6a** shows an alternative circuit giving lower distortion by using n fets for better matching. Here $Tr_{7,9}$ are acting as virtual complements.

Gain matching of each half is achieved with $RV_{2,3}$ in series with small signal diodes $D_{5,6}$. This compensation method is effective, allowing large gain variations in bipolar transistors as well as partly linearising beta fall-off in the bipolar transistors above 1A.

Usually, the output transistors have a resistor directly across the base-emitter terminals to remove base leakage current and speed up turn off. These resistors are not used in this application. This is due to the fact they cause unacceptable non-linear gain at low currents.

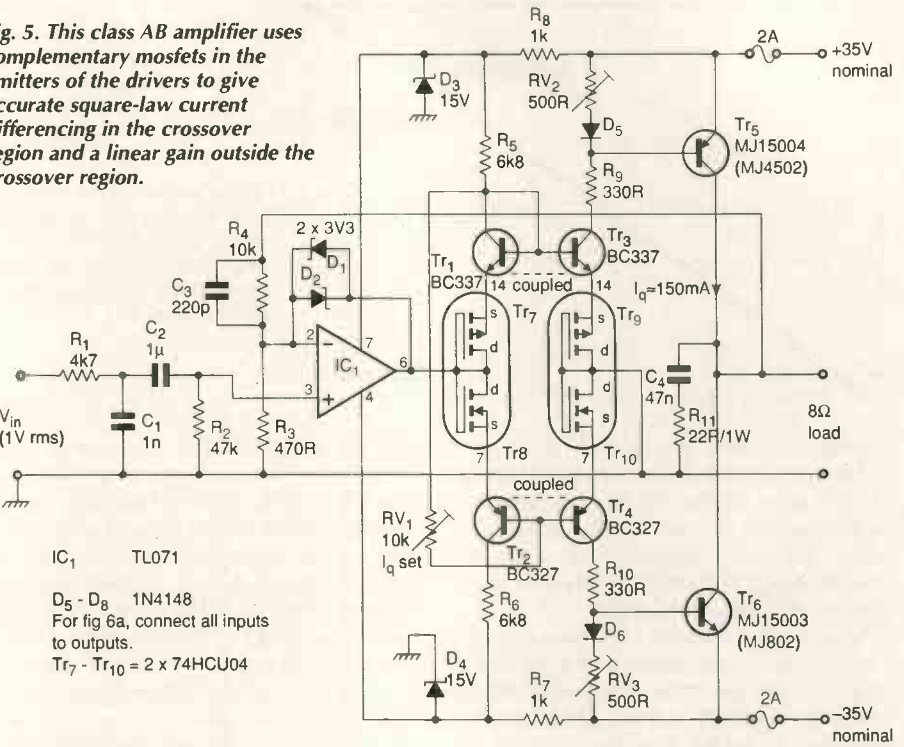
One solution to prevent thermal run-away is to keep the transistors cool with a larger heatsink. An alternative is the circuit of Fig. **6b**. Temperature sensing diodes $D_{7,8}$ can be soldered to a lug held by the TO3 bolt to the case of $Tr_{5,6}$. High-gain transistors $Tr_{11,12}$, with $\beta \geq 300$ across the base-emitter terminals, remove the temperature-dependent leakage current and prevent thermal run-away allowing minimal heatsinks.

In Fig. 5, fets $Tr_{7,8}$ are used as a bias voltage generator. They maintain a constant bias current through fets $Tr_{9,10}$ since current through $Tr_{7,8}$ is mirrored into $Tr_{9,10}$ independent of ambient temperature changes. Impedance of the bias generator is small compared to $R_{5,6}$ supplying the bias, being $1/g_{fs}$ where g_{fs} is $\sqrt{2\beta I_D}$ or 100Ω since I_D is 1mA.

With a low impedance voltage drive there is little incremental drop across the bias generator as the input voltage varies. Since the input voltage swing is only ±2V, resistors $R_{5,6}$ can be used rather than active current sources to set the bias current.

Power supply ripple rejection is about 30dB, with zeners $D_{3,4}$ providing another 30dB. Transistors $Tr_{1,2}$ compensate for temperature change in $Tr_{3,4}$ since they are coupled thermally. Higher power versions will require a heatsink. Tests on the 50W version were done without this heatsink.

Fig. 5. This class AB amplifier uses complementary mosfets in the emitters of the drivers to give accurate square-law current differencing in the crossover region and a linear gain outside the crossover region.



Transistors $Tr_{3,4}$ act as voltage followers. Input voltage is transferred to the gates of $Tr_{9,10}$. The resulting drain currents are level shifted by $Tr_{3,4}$ to drive the output transistors. Resistors $R_{9,10}$ limit the output current for output shorts to prevent secondary breakdown. At a V_{ce} of 50V, the I_{SB} rating for these transistors is 4A.

Resistors $R_{9,10}$ can be calculated assuming a beta of 50 at 4A. As a result, base current is 80mA so 30V across $R_{9,10}$ requires 330Ω resistors. These resistors also reduce dissipation in the drivers, allowing free-standing TO92 devices for a 50W version. Transistors $Tr_{5,6}$ have gains of 110 and 80 respectively at 1A, both falling to 50 at 5A. *MJ15003/4*s were used because of availablity, but the *MJ802/MJ4502* pair is a better choice for a 50W version with similar I_{SB} ratings at half the cost.

Typically, the bias voltage for optimum bias of 150mA was 1.7V in Fig. 5, with 785mV across n-channel fet Tr_8 and 863mV across the p-channel fet Tr_9 – a difference of 83mV.

This is attributed to differences in the p-n threshold voltages. It was found to cause one side to finish its square-law before the other and so give non-linearities toward the ends of the crossover region. These could not be trimmed out since the fets are internally coupled.

Using all n-channel fets for $Tr_{7\text{-}10}$, Fig. 6a, the bias voltages were to within 6mV and nonlinearity in the crossover region was removable by trimming the quiescent current.

Digital meters were used in a static test to accurately measure Fig. 5's *V-I* transfer function at each half of the collectors of $Tr_{3,4}$ before the output stage. Plotting the results manually showed surprisingly linarity to meter accuracy of ±0.1% right up to 100mA.

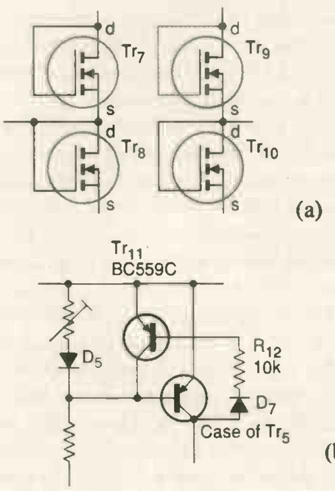


Fig. 6a) Alternative arrangement for Tr$_{7\text{-}10}$, *giving better matching. Transistors $Tr_{7,8}$ are virtual complements. Use four 74HCU04s for* Tr$_{7\text{-}10}$. *Source is pin 7. Leave pin 14 floating.*
Fig. 6b) Collector-base leakage current compensation circuit to prevent thermal runaway in Tr$_5$. *A similar circuit is used for* Tr$_6$, *not shown.*

However, the gain of each half was different, at 69mA/V and –64mA/V. This is compensated for in this circuit using $RV_{2,3}$.

Points where the fets change from square-law to linear were considerably different – from 20mA upwards and –25mA downwards. Another plot of $\sqrt{I_D}$ *versus* V_{in} showed the square-law relationship was accurate up to the 20/25mA points.

The reason for the abrupt change from square-law to linear required for class-AB is not yet fully understood. It may be caused by pinch-off, where the fet changes from current

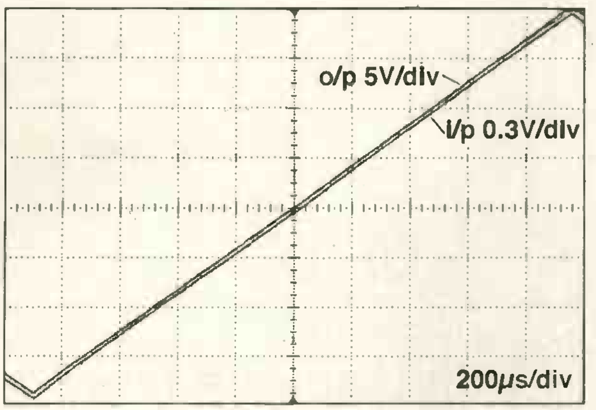


Fig. 7. Output of circuit of Fig. 5 but all n-fets (Fig. 6a) with a triangle wave input shown for comparison. It shows the open loop linearity before applying global feedback.

saturation to resistive mode as I_D increases.

Dynamic testing of the output stage of Fig. 5, after trimming for best linearity showed a 0.2V deviation over ±20V. When plotted, the static test also showed 0.2V deviation. Distortion at 500Hz was 0.3% when the swing reached 60% of the full output.

Most of the harmonics were third and fifth order. Voltage gain was 13 with an 8Ω resistive load. Full power bandwidth was 70kHz, and gain-bandwidth product 1MHz. Second harmonic switching distortion, seen on an oscilloscope as differences in the bandwidth of the output transistors, reached a maximum of 3% at 10kHz and 33V pk-pk, first noticeable at 2kHz. At 5kHz distortion is 1%.

The negative side is the slower half and generally has the higher gain. This allows a 10Ω resistor in parallel with a 1μF capacitor to be added in series with the emitter of Tr_4 to give lead compensation to the slower half. This allows switching asymmetry to be almost cancelled over the audio range, giving similar open-loop distortion levels to the power fet circuit of Fig. 2. In closed-loop the power fet circuit can achieve lower distortion due to higher open-loop gain and bandwidth.

Modification Fig. 6a reduced total harmonic distortion after trimming by a factor of 3 to 0.1% at 500Hz. **Figure** 7 shows the open-loop transfer curve. Based on the static test, remaining non-linearity is probably due to the bipolar output transistors. There was only a slight temperature induced change in linearity, observed between idle and running continuously at maximum power.

Load impedance changes did not have any noticeable affect on linearity for the same output current swing. Without collector-base leakage compensation, quiescent current through the output transistors would rise from 150mA of optimum bias, to 230mA after running at full power for some time. This variation does not affect linearity.

Circuit Fig. 6a has demonstrated that a stable 0.1% thd can be achieved up to 2kHz open loop with a gain of 13 using readily available non-selected parts. Closed-loop distortion could not be measured with the *HP54601A* using FFT. Closed loop thd however is expected to be 0.001% at 1kHz and 0.006% at 20kHz. This assumes an *TL071* providing about 40dB feedback at 20kHz.

In closed loop, C_3 provides some phase advance above 70kHz – the output stage roll-off point – keeping the loop phase less than 180° until the gain has fallen below unity.

Using similar transistors in a complementary feedback-pair output stage, Self's Fig. 8 class-AB amplifier of reference 2 shows distortion reaching 0.01% at 20kHz, using a 37dB feedback factor at 20kHz. This he attributes mainly to crossover and switching distortion.

With a 37dB feedback factor, output stage distortion can be calculated to be 0.7% with optimal biasing – 50 times higher than the 0.014% expected from an optimally biased complementary-feedback pair[14]. Presumably the 0.7% figure is mostly due to switching distortion and not component mismatch. The emitter resistors determine gain matching at high current – not the transistors.

The fet output stage is expected to give 0.001% thd at 20kHz since it has higher gain and wider bandwidth allowing a higher feedback factor at 20kHz. It is also expected to match the class-A design of 0.0012% at 20kHz by Self[10,4] with a similar spread of low order harmonics.

Setting optimum bias

I developed a straightforward technique for setting optimum biasing using an oscilloscope and triangle wave source. The alignment is carried out with an open loop by connecting a 100μF capacitor across D_1. Trimming is best achieved at about 50% of the maximum output swing by applying about 1.5V peak triangle wave with an 8Ω resistive load.

Display the input and output waveforms together, as Fig. 3. Set RV_1 at zero and $RV_{2,3}$ at maximum. Raise quiescent current to about 150mA then determine which half shows the lowest slope. If, for example, the lower half has the lower gain then vary RV_1 for best linearity – lower half only. Lastly, reduce RV_2 until the upper half has the same slope as the lower half. The overall line should then be straight.

Better things yet to come?

The static test showed that given a sufficiently linear current mirror output stage, crossover and high-end gain deviation could go as low as ±0.1% for open loop class-AB. If this were achieved, the output stage alone could go as low as 0.001% thd with unity gain, since open loop gain ≥10. This would be two orders of magnitude lower than the best possible using classical class-AB circuits.

A technique that gives an output stage excellent linearity has been used in a fast power amplifier[15]. As for bias stability, integrating $Tr_{1\text{-}4}$ and $Tr_{7\text{-}10}$ on the same chip must provide ultimate performance. Integrating can also allow automatic biasing using a slave circuit[16] to monitor linearity and correct any changes.

In summary

Preliminary results from two different class-AB circuits show the square-law nature of fets can be used to reduce distortion below the levels of classical fet and bipolar output stages. The only drawback is that two presets are used for alignment instead of one, as is normally the case.

It is pleasing to see fets go linear at higher currents in a way that allows near elimination of class-AB crossover distortion. Two different techniques have demonstrated that class-A performance is possible using class-AB – one circuit using power fets over their full current range, and the other using fets driving bipolar power transistors.

Bipolar output-stage bandwidth degrades performance above 2kHz. The power fet output stage is free from switching distortion and allows more feedback at the top audio end giving superior overall performance. These fet based circuits demonstrate that class-A performance need not be traded for class-AB efficiency.

I would like to thank Manawatu Polytechnic, New Zealand for its help in preparing this article. ■

References

1. Williams, M, 'Making a linear difference to square-law fets', *EW+WW*, Jan 94, p. 84.
2. Self, D, 'Distortion in Power Amplifiers: Part 5', *EW+WW*, Dec 93, p. 1010.
3. Blomley, P, 'New Approach To Class B', *WW*, Feb 71, p. 57.
4. Self, D, 'Distortion in power amplifiers: Part 7', *EW+WW*, Feb 94, p. 137.
5. Finnegan T, 'Going linear with power mosfets: Part 1', *EW+WW*, Aug 92, p. 637.
6. Self, D, 'Common emitter amplifiers', *EW+WW*, July 94, p. 550.
7. Brown, I, 'Between amplifier and speaker', *EW+WW*, Feb 95, p. 114.
8. Brown, I, 'Feedback and fets in audio power amplifiers', Feb 89, *EW+WW*, p. 126.
9. Moir, J, 'Just detectable distortion levels', *WW*, Feb 81, p. 34.
10. Self, D, 'Distortion in power amplifiers: Part 8', *EW+WW*, March 94, p. 226.
11. Cherry, E, Ironing out distortion, *EW+WW*, Jan 95, p14.
12. Giesberts, T, '1000-Hz sine wave oscillator', *Elektor Electronics*, Dec 94, p. 5.
13. Duncan, B, 'How clean is your op-amp?' *EW+WW*, Jan 93, p. 42.
14. Self, D, 'Distortion in power amplifiers: Part 8', *EW+WW*, Nov 93, p933.
15. Hegglun, I, 'Fast power amplifier for audio', *EW+WW*, Mar 95, p. 240.
16. Park, C, Schaumann, R, 'Design of a 4MHz Analog Integrated CMOS Transconductance-C Bandpass Filter', *IEEE, J. Solid-State Circuits*, Vol 23, No. 4, Aug 88, p. 987-996.

Recording on demand

As a learning aid for advanced students, note taking is only useful to the dextrous. François Steenkeste's delayed recorder is designed to make the alternative – tape recording lessons – a much more efficient process.

Note-taking is a complex activity requiring listening, thinking, manual dexterity and eyesight. Not everyone takes notes equally well. Visually impaired people for example can be at a distinct disadvantage at university, when note taking skills can make the difference between a pass and a fail.

Tape recordings help, but sorting a few useful ideas from a long speech can be very time consuming.

With the note-taking aid described here, speech is recorded into a rolling buffer memory. When the listener perceives that an important point has been made in the speech, he or she simply presses the record button – after the event.

Unlike a tape recorder, this system records not the real-time speech, but a delayed representation of it. In this way, ideas already spoken can be recorded provided that the button is pressed before the rolling delay has expired.

Delayed recording details

To obtain a few seconds delay, a digital memory and a-to-d/d-to-a converters are used, **Fig. 1**. Memory is organised as an endless loop by a memory controller, making it easier to reconstruct the audio-signal after the delay.

Digital information coming from the microphone via the a-to-d converter is sent to ram address x by the memory controller. During the same sample period, the memory controller reads the bits contained in the ram address $x+1$, incrementing the address counter by one ready for the next read/write. These three operations are repeated each sample period.

If the endless loop contains n addresses, the information stored at address x will be read n sample periods later. One complete memory cycle time, d, is represented by the time taken to sample one converter reading multiplied by the total number of addresses.

The d-to-a converter receives this information and sends the corresponding analogue signal towards the magnetic head. Provided the listener operates the remote control before the end of the delay period, the motor turns on and the signal is recorded.

The three switches of **Fig. 2** represent analogue multiplexers/demultiplexers. These give access to the recording and playback functions of the recorder. They are controlled by the keyboard via logic. If $S_{1,2}$ are in position A, the device records. In position B, playback takes effect. Delay position, *A*, and the normal position, *B*, are controlled by S_3.

Playback circuitry is provided by the OKI *MSM6310*. This device is designed for endless loop recording in eight-bit pulse-code modulation and is used to drive the endless loop.

Three units make up the internal circuit. The input unit comprises a line amplifier, low pass filter and eight-bit a-to-d converter. An eight-bit d-to-a converter followed by a low pass filter forms the output unit. Finally, there is a control unit for one or two dynamic-ram segments. This control unit also drives the remote control, motor and sample frequency.

Delayed recording and repeated playback depend on the remote control. When the operator presses the button, the motor command is given by an output from the *MSM6310*. In the case of delayed recording, the analogue signal corresponding to the idea spoken d seconds earlier is recorded on tape.

When the speaker finishes giving relevant information, the listener presses the remote control a second time. After delay d, the motor is stopped. This avoids losing the last piece of information contained in the endless loop memory.

In the repeat mode, the user operates the remote control in order to re-hear the last seconds of playback. Consequently, the motor is stopped and the memory content is repeated on the loudspeaker until a second action on the remote control turns the motor back on.

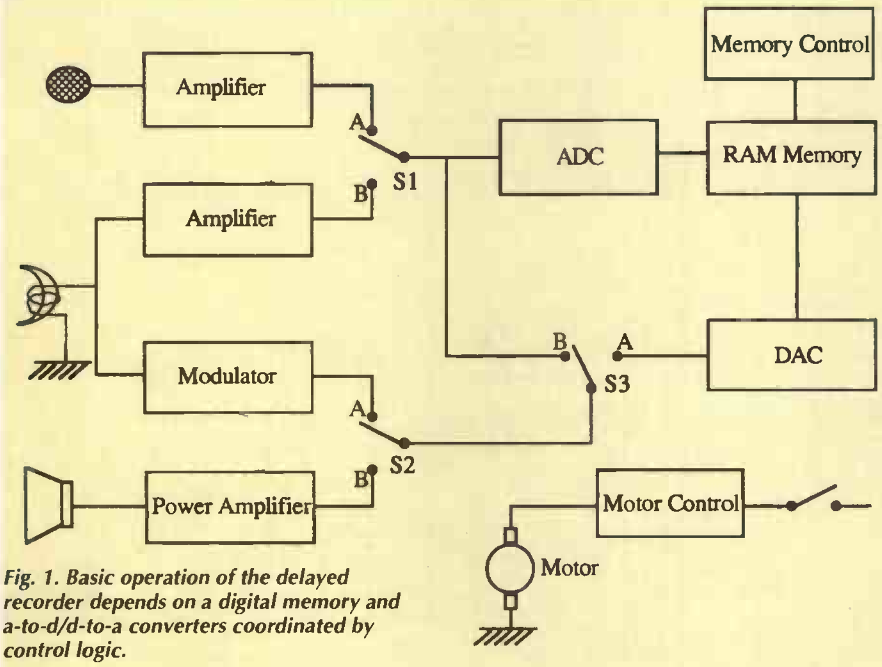


Fig. 1. Basic operation of the delayed recorder depends on a digital memory and a-to-d/d-to-a converters coordinated by control logic.

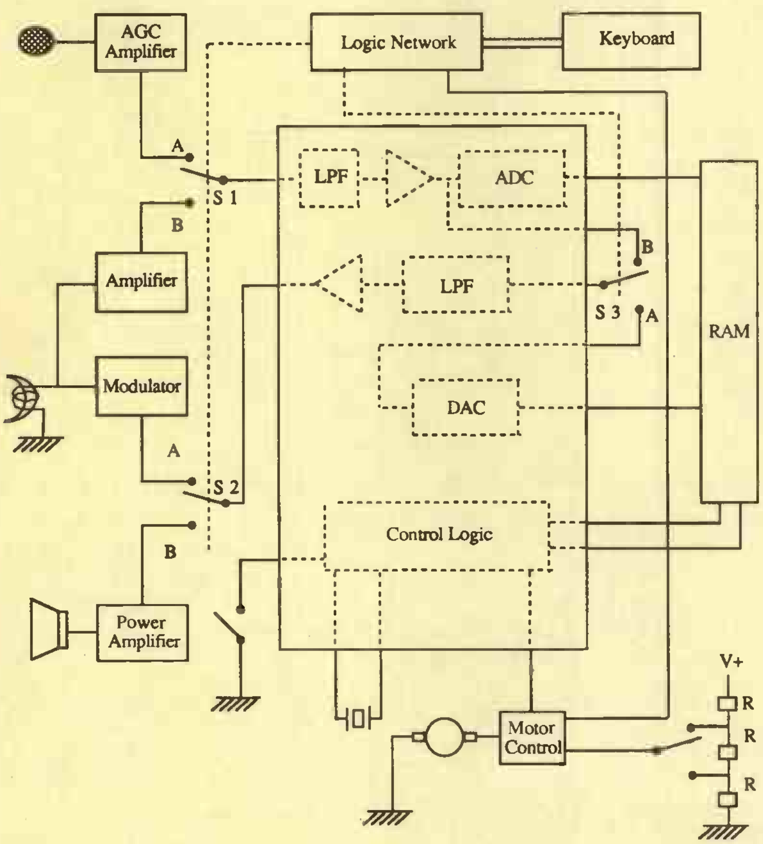


Fig. 2. Delayed/normal recording together with repeat/normal playback functions of the recorder are achieved through analogue multiplexers/demultiplexers controlled via a logic network.

Implementing the recorder

At the heart of this recorder is the *MSM6310* controller, connected to two 256K×1-bit *MSM41256* dynamic rams, **Fig. 3**. The device controls address lines, column address strobe signals, row address strobe signals and the memory write enable signals.

Double-pole, three-way slide switch Sw_4 allows selection of delay time with a duration of 2, 4 or 8 seconds by controlling both RAMS and FSS inputs. A high level to the RAMS input informs the *MSM6310* IC that an external dynamic ram is connected. When the same level is applied to the FSS input, the crystal frequency of 8MHz is divided by 1024, giving around an 8kHz sampling frequency. If this level is low, the divisor is 512, doubling the sampling frequency.

Analogue section

Recording and playback are provided by the analogue section, under control of the *4053B* analogue multiplexer-demultiplexer. When the Ob_4 NOR gate output is low, the microphone's signal is recorded on the tape.

Transistor Tr_6 buffers the built-in microphone signal and feeds an *SL6270* gain controlled pre-amplifier. This IC is designed to accept signals from a low sensitivity microphone and provide a constant output signal for a 50dB input range.

Dynamic range, attack and delay times are controlled by the R_{35}/C_{14} network. The signal is amplified by the *MSM6310*, whose 40dB gain is fixed by network R_{38}/R_{40}. The amplifier output, AMPO, together with the output of the internal d-to-a converter, DAO, is connected to the analogue multiplexer-demultiplexer. Output of the multiplexer-demultiplexer is linked to the *MSM6310* low-pass filter.

This implementation allows the user to choose between a recording with or without delay, DAO/AMPO. Amplifier A_3 mixes the low-pass filter output with the 33kHz signal of controlled oscillator A_2 and a 50Hz signal from oscillator A_4.

Oscillator A_4, controlled by Sw_7, allows marking of the start of a new recording. The mixed signal is then sent through the R_{58}/C_{27} network into magnetic head H_1. During recording, erase head H_2 and oscillator A_2 are activated by a high level on R_{34} and R_{51}.

Conversely, in playback mode, the Ob_4 NOR gate output is high. In this instance, the audio signal is supplied by the tape, through the magnetic head H_1, and amplified by Tr_8. During playback, this signal's source replaces the microphone in the amplifier chain detailed above. In the same way, during playback, amplifier A_3 output is connected to the *MSC1191* power amplifier and the built-in speaker.

Figures 4 and **5** show the bandwidth of the

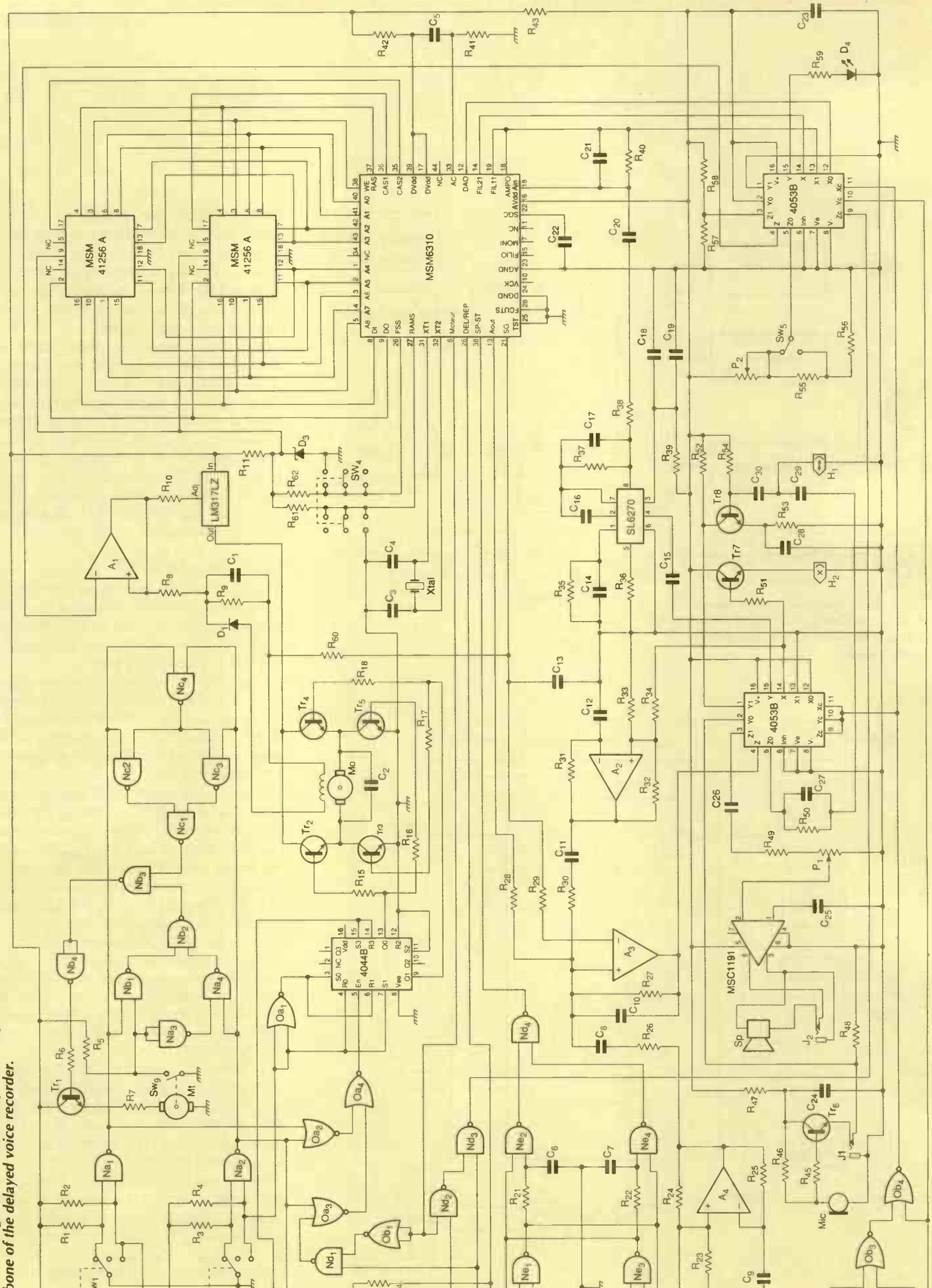
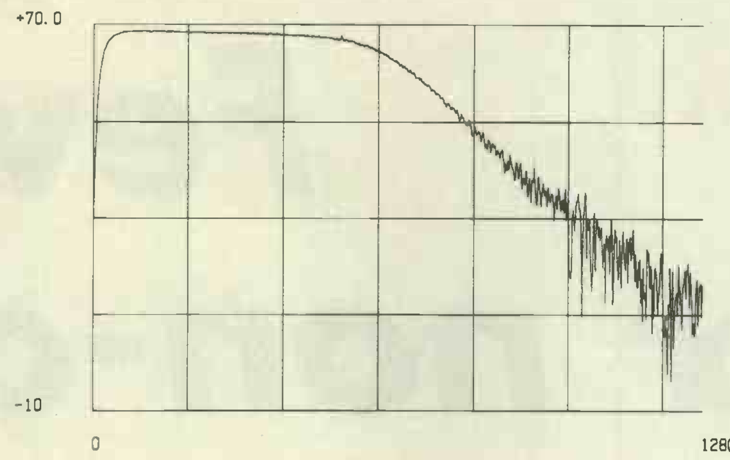


Fig. 3. The MSM6310 - designed for endless loop recording in 8-bit pcm - is the backbone of the delayed voice recorder.



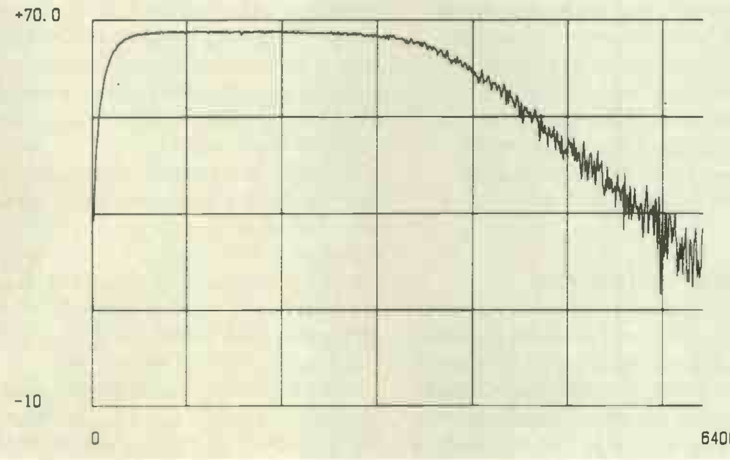


Fig. 4. A 16kHz sampling frequency, with a delay of 2 or 4 seconds, results in a –3dB bandwidth of 270-5600Hz. Horizontal scaling is 2kHz/div and vertical is 20dB/div.

Fig. 5. At eight seconds, sampling frequency falls to 8kHz, resulting in a bandwidth of 260-3450Hz. Horizontal scaling is 1kHz/div while vertical is 20dB/div.

amplification chain between the Tr_6 and AOUT of the *MSM6310*. When the delay time is fixed at 2 or 4 seconds, the sampling frequency is 16kHz. This results in a –3dB bandwidth equal to 270-5600Hz, Fig. 4. At 8 seconds, the sampling frequency reduces to 8kHz and the bandwidth to 260-3450Hz, Fig. 5.

Logic section

The logic circuitry is designed to drive an electrically-controlled mechanism made by Olympus. The heads are positioned by a dc motor driving a gearwheel and cam. This closes Sw_3 when the magnetic heads are near the tape.

Main functions of the recorder are controlled by slide switches. Playback/record is controlled by Sw_1 and rewind/fast forward by Sw_2. Output levels of gates $Na_{1,2}$ and the status of Sw_3 drive the exclusive-or circuit comprising NAND gates Na_3 and Nc_4.

The tape motor is driven by two three state set-reset latches within the *4044B*, connected to transistor network Tr_{2-5}. Tape direction is indicated by Oa_1. Control depends on Sw_1-Sw_2 and the 'motor' output of the *MSM6310* circuit, through a logic network comprising four two input NOR gates $Oa_{2,1}$ and Nd_1.

The motor has an inductive tachymetric generator whose output signal is used to adjust the motor's speed. This signal is compared with a reference voltage from resistor networks R_{57}/R_{58} or $P_2/R_{55}/R_{56}$, by amplifier A_1. This amplifier controls the *LM317* adjustable regulator.

Network R_{57}/R_{58} indicates fast forward and rewind. The two-position slide switch Sw_5 allows the user to choose the tape speed of 2.4cm/s or 1.2cm/s.

Record/playback switch Sw_3 drives the input DEL/REP of the *MSM6310* and controls the analogue switch of the *4053B* via $Nd_{2,3}$. In addition, contact Sw_8 on the microcassette holder detects whether the cassette can be erased. If the cassette's erase-protection tab is broken, gates Ob_{2-4} prevent the multiplexers/demultiplexers from establishing the recording circuit.

Finally, Sw_6 together with gates Nd_4 and Nc_{1-4} create the start/stop pulses. These pulses drive the motor output of the *MSM6310* during delay and repeat modes.

	Non handicapped	Motor handicapped
Written notes	80%	71%
Recorded notes	–	90%

Table 1. These results show that motor-handicapped students using the delayed recorder take notes more efficiently than non-handicapped students taking notes conventionally.

Results

We have tested this recorder with different student groups during their courses. During the first experiment, motor handicapped pupils used delayed recorders set for four second delay. In addition, non-handicapped pupils aged 13 from the French fifth form took notes.

Approximately a quarter of the lesson was recorded. Pupils who used the recorder took note of 90% of the main information, while the non-handicapped pupils wrote down less than 80% of main information. However, the pupils were not very selective and had difficulty appreciating what could be said in four seconds.

A second experiment took place during the psychology and physiology courses of the Universite de Lille. A blind student recorded his course notes with the delayed recorder. The capacity of the endless loop was set to two seconds.

It was possible for this student to select and record complete sentences without losing the first words. Recording duration lasted less than 50% of the course.

Initial findings

Results obtained using a delayed tape recorder have shown that selective recording during courses is practicable. Using prototypes, we reached the following conclusions:

- Due to ram limitations, it is more difficult to take notes with a four-second delay than with two seconds.
- Delayed recording facilitates rapid selection of information.
- Recordings made are shorter than the lessons, reducing the amount of post-analysis needed by the students. ■

References

1. Nguyen, D.D, Steenkeste, F, Moschetto, Y, Sizaire, P, Ledru, C, 'Aide technique a la prise de notes chez les handicapes moteurs : le magnetophone enregistrement differe', *ITBM*, Vol. 8, No 5,1987, p. 569-577.
2. Steenkeste F, Lesage J.C, Dhelin G, Moschetto Y, 'Un outil pour la prise de notes : le magnetophone a enregistrement differe et a compression temporelle', *ITBM*, Vol. 12, No 2, 1991, p. 213-222.
3. Steenkeste, F, Lesage, J.C, Dhelin, G, Moschetto, Y, 'Delayed recording to facilitate the educational integration of people with disabilities.' *International Journal of Rehabilitation Research*, Vol. 16, No 3, Sep. 1993, p. 239-244.
4. Data book, 'OKI Voice Synthesis LSI', Fourth Edition, Mar. 1992.
5. Professional Products IC Handbook, GEC Plessey Semiconductors, May 1991.

Few ... for non-co

Douglas Self takes issue with Bengt Olsson's non-complementary power amplifier design, arguing that the two-stage approach is not necessarily simpler or better than the traditional three-stage design.

Bengt Olsson's most interesting article on quasi-complementary fet output stages[1] prompted me to examine how his proposed configuration works. Investigations showed that his scheme changes not just the output stage but the entire structure of the amplifier, and it presents some intriguing new design problems.

An alternative architecture

Nearly all audio amplifiers use the conventional architecture I have analysed previously.[2] There are three stages, the first being a transconductance stage, ie differential voltage in/current out, the second is a transimpedance stage ie current in/voltage out and lastly a unity-gain output stage, **Fig. 1a**.

Clearly, the second stage has to provide all the voltage gain and is therefore formally named the voltage amplifier stage, or vas. This architecture has several advantages. A main benefit is that it is straightforward to arrange things so that the interaction between stages is negligible. For example, there is very little signal voltage at the input to the second stage, due to its current-input nature. This results in very little voltage on the first stage output, which in turn minimises phase-shift and possible Early effect.

In contrast, the architecture presented by Olsson is a two stage amplifier, **Fig. 1b**. The first stage is once more a transconductance stage, though now without a guaranteed low impedance to accept its output current. The second combines voltage amplifier stage and output stage in one block. It is inherent in this scheme that the voltage amplifier must double as a phase-splitter. This results in two dissimilar signal paths to the output, and it is not at all clear that trying to break this block down further will assist a linearity analysis. The use of a phase-splitting stage harks back to valve amplifier days, when it was essential due to the lack of complementary valve technology.

Since the amount of linearising global feedback available depends upon amplifier open-loop gain, the way in which the stages contribute to this is are of great interest. The normal three-stage architecture always has a unity-gain output stage – unless you really want to make life difficult for yourself. As a result the total forward gain is simply the product of the transconductance of the input stage and the transimpedance of the voltage amplifier stage. Transimpedance is determined solely by the Miller capacitor C_{dom}, except at very low frequencies[3].

Typically, the feedback factor at 20kHz will be 25-40dB. It will increase at 6dB per octave with falling frequency until it reaches the dominant pole frequency P_1, when it flattens out. What matters for the control of distortion is the amount of negative feedback, nfb, available, rather than the open-loop bandwidth, to which it has no direct relationship.

In my *EW+WW* Class-B design, input stage g_m is about 9mA/V, and C_{dom} is 100pF, giving a feedback factor of 31dB at 20kHz. In other designs I have used as little as 26dB at the same frequency with good results.

Arranging the compensation of a three-stage amplifier can be relatively simple. Since the pole at the voltage-amplifier stage is already dominant, it can be easily increased to lower the hf negative-feedback factor to whatever level is considered safe. The local negative feedback working on the voltage amplifier has an invaluable linearising effect. I am aware that some consider there are better ways to perform this sort of compensation, but the Miller approach is so far the most stable method in my experience.

Fewer stages, more complexity?

Paradoxically, a two-stage amplifier may be more complex in its gain structure than a three-stage. Forward gain depends on the input-stage g_m, the input-stage collector load, and the gain of the output stage, which will be seen to vary in a most unsettling manner with bias and loading. Input-stage collector loading plays a part here since the input stage can not be assumed to be feeding a virtual earth.

Choosing the compensation is also more complex for a two-stage amplifier. The voltage-amplifier/phase-splitter has a significant signal voltage on its input. Usually, the pole-splitting mechanism enhances Nyquist stability by increasing the pole frequency associated with the input stage collector. But because of the relatively high voltage on the voltage-amplifier/phase-splitter, the pole-splitting mechanism is no longer effective.

compliments mplements

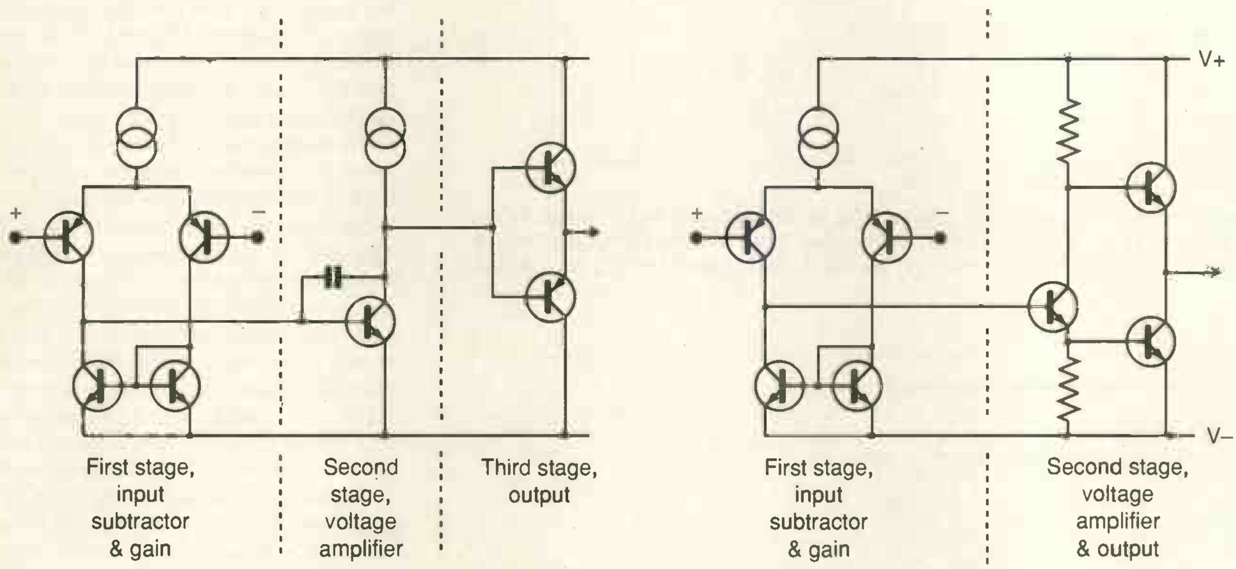


Fig. 1. Conventional three-stage amplifier architecture, and two-stage architecture advocated by Olsson.

This may be why Olsson's circuit uses a cascoded input stage comprising $Tr_{6,7}$ in his original circuit, Fig. 11. This presents the input device collectors with a low impedance and prevents a significant collector pole. Another valid reason is that it also allows the use of high-beta low-V_{ce} input transistors, which minimise output dc offset due to base current mismatch. This is usually much larger than the dc offset due to V_{be} mismatch.

Such an input cascode can also improve power-supply rejection as it prevents Early effect from modulating the subtractive action of the input pair.

Simple calculation gives the g_m of Olsson's amplifier as 16mA/V, but the effective gain of the next stage seems much more difficult to equate. A full *PSpice* simulation of the complete amplifier with an 8Ω load shows that the feedback factor is 36dB up to 300Hz. It then rolls off at the usual 6dB/octave, until it passes through 0dB at about 20kHz. This 36dB represents much less feedback than the three-stage version. It indicates that C_{dom}, notionally connected between drain and gate of M_3, must be comparatively very large at approximately 3nF.

Specified internal capacitances of M_3 are certainly orders of magnitude larger than those of an equivalent bipolar device – they vary from sample to sample and also with operating conditions such as V_{ds}. These unwanted variations would appear to make stable and reliable compensation a difficult business.

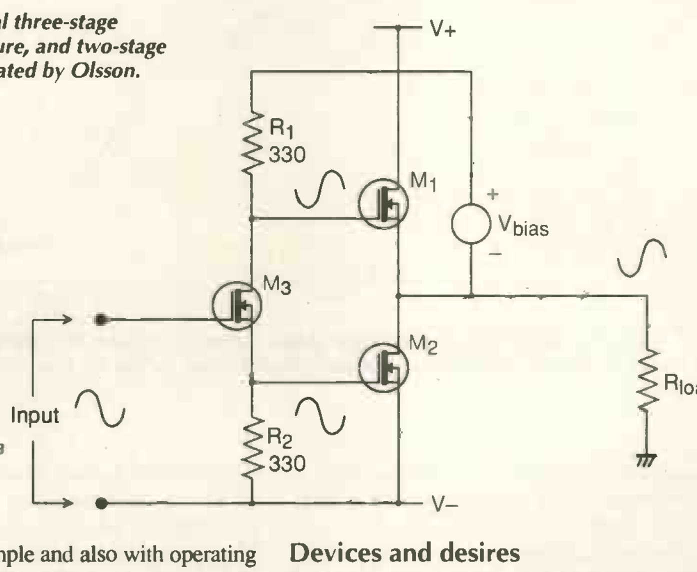


Fig. 2. Basic fet output stage used for simulations of Figs 3, 4 and 5. Transistors $M_{1,2}$ *are* IRF240 *and* M_3 *is* IRF710.

The low-frequency feedback factor is about 6dB less with a 4Ω load, due to lower gain in the output stage. However, this variation is much reduced above the dominant pole frequency, as there is then increasing local negative feedback acting in the output stage.

Devices and desires

In his opening paragraph, Olsson says that the symmetry of complementary transistor output stages is theoretical rather than practical. Presumably he is referring only to power-fets, as suitable pairs of bipolar devices, such as Motorola *MJ802/MJ4502* – old favourites of mine – exhibit excellent symmetry.[4] Admittedly, the two devices are not exact mirror-images, but the asymmetries are small

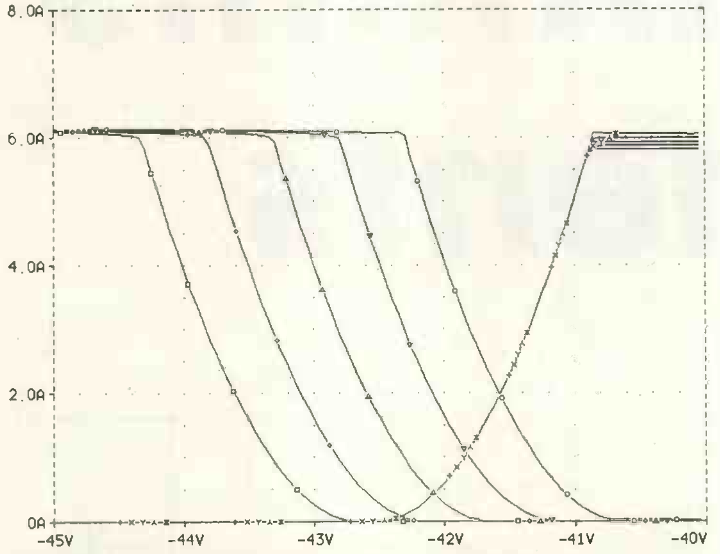


Fig. 3. Drain current in each output fet when driving an 8Ω load, with V_{bias} stepped. As V_{bias} increases the I_d (M_1) line moves to the right and overlaps more with the I_d(M_2) line. In each case symmetry exists about the intersection of the two I_d lines. Values for V_{bias} are 7.5, 8, 8.5, 9 and 9.5V.

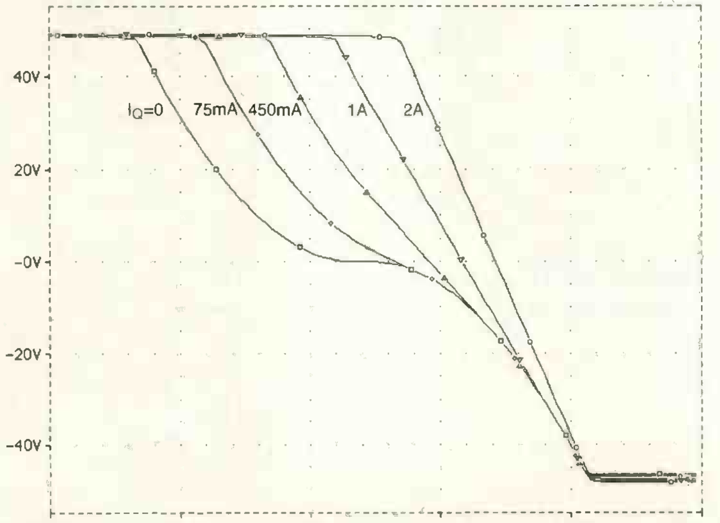


Fig. 4. Output transfer functions for stepped bias voltage. For lower bias, the characteristic is sigmoidal – S-shaped, unlike a conventional Class-B stage. Values for V_{bias} are 7.5, 8, 8.5, 9 and 9.5V.

enough for even-order harmonic generation in the output stage to be negligible. This is surely what counts.

This symmetry does not hold for power-fets however, and so it may be that some of Olsson's concern with symmetry flows from an initial decision to use fets. I find it difficult to understand why power fets in particular suffer from so many mis-statements. It is still confidently held that fets are more linear than bipolars, although the opposite is certainly the case when the two types of device are used in normal Class-B output stages.

Similarly, fet robustness is often exaggerated, the devices being prone to summary explosion under serious parasitic oscillation. Mercifully bipolars are not. In particular, I find it hard to understand Olsson's contention that fet parameters are predictable – they are notorious for being anything but.

From one manufacturer's data, namely Harris, the V_{gs} for the *IRF240* varies between 2 and 4V for an I_d of 250μA – a range of two to one. In contrast the V_{be}/I_c relation in bipolars is fixed by a mathematical equation for a given transistor type. The exponential relationship may be regarded as more non-linear than the partially-square-law fet V_{gs}/I_d relationship but it is dependable, and gives a much higher transconductance. This can always be traded for linearity by introducing local negative feedback.

Output considerations

Figure. 2 shows the basic output configuration I have investigated. I have not examined the 'anti-saturation' schemes intended to provide the output fets with extra gate drive.

My first discovery is that the voltage-amplifier stage/phase-splitter does not have to be a fet. Replacing it with a bipolar junction transistor, for example *MPSA92*, gives almost identical results. I have used $M_{1,2}$ etc rather than $Tr_{1,2}$ for fet designations as this preserves consistency with the *PSpice* output.

This output stage configuration is totally different in operation from the conventional Class-B stages discussed in reference 1. It is a hybrid common-drain/common-source configuration, or, in bipolar speak, a common-collector/common-emitter (cc-ce) stage. In this sort of output, the upper emitter-follower has a common-emitter active-load. This load may or may not deliver an appropriate current into the node it shares with the upper device.

The input-voltage/output-current relationship for the upper and lower devices will be different, as a result of the two dissimilar paths to the output. This means that while such a stage can always be biased into Class-A by increasing the quiescent enough[5] there is every likelihood that it will be an inefficient kind of Class-A. It will deviate seriously from the constant-sum-of-currents condition that distinguishes classical Class-A.[6]

Lower quiescents tend to give a depressingly non-linear and asymmetrical Class-AB. In general there is no equivalent at all to standard Class-B, where the symmetry of the configuration – rather than anything else – allows both output devices to be biased to the edge of conduction simultaneously.

In general, cc-ce stages generate large amounts of even-order distortion, due to their inherent asymmetry. I appreciate however that avoiding this is one of the prime purposes of Olsson's circuit.

In **Fig. 2**, the position of V_{bias} causes a form of bootstrapping, and I can confirm that driving it from the output is essential to make the scheme work.

Figure. 3 shows drain current in each output fet when driving an 8Ω load, with V_{bias} stepped, as simulated by *PSpice*. Compared with conventional Class-B, the drain currents cross over smoothly. This seems intuitively a good idea, and has been recommended by several writers, but in fact a smooth-looking current crossover does not guarantee a linear composite gain characteristic.

Figure 4 shows the input/output characteristic for the stage. You can see that the lower

V_{bias} levels produce a sigmoidal transfer function, with gain falling off in the crossover region. This gross output distortion is much greater than that given by a normal Class-AB stage. It suggests that it is only practical to run the stage in full Class-A, see the straight line at the right of the plot. I do not recall a mention of this point in the original article.

Quiescent current needed to achieve this is about 2A. The desirability of Class-A operation is reinforced by the incremental gain plot in Fig. 5. It is clear that the gain variations are serious for lower V_{bias}, and do not augur well for the closed-loop distortion performance. Only the rightmost Class-A gain characteristic has a clear flat portion over its operational range.

It is true that the drain currents in this stage are symmetrical – but the quiescent required to remove the sharp-eared 'Batman' effect in Fig. 5 is so high that the amplifier is working entirely in Class-A. The symmetry of the circuit means only that when distortion is produced, it will be predominantly odd-order, which is not normally considered a good thing from the subjective point of view. To keep the stage linear into 4Ω loads would demand a quiescent of 2.9A. It is interesting that this is not twice the current for the 8Ω case.

There are other significant differences from the usual voltage-follower configuration, which if nothing else has a stage gain reliably close to unity. Olsson's output stage gain varies with V_{bias} adjustment – even when in Class-A – and also varies strongly with load impedance. This would seem to make reliable compensation a difficult business, but in the complete amplifier this variation is probably only significant below the dominant-pole frequency P_1.

Figure 6 is a comparison between the Olsson configuration and three conventional stages, all biased to drive an 8Ω load in Class-A. Traces 1 and 2, at the top, are bipolar-emitter follower and complementary-feedback-pair stages. These produce the usual linearity and close approach to unity gain.

The curved lower trace, 4, is a conventional complementary fet output. Trace 3 is the Olsson stage, with its gain of about 65 times normalised to fit in between the other curves. It shows stronger curvature than the bipolar stages, and despite everything, is actually less symmetrical than the usual output stages. I think this is inherent in the circuit's lack of symmetry about the output line.

I hope this article is a fair analysis of the proposed configuration, and that I have not made any serious misinterpretations of Mr Olsson's intentions. I also trust that it will not be taken as purely destructive criticism, for that is not my intention. I have to conclude that the configuration appears to require a very high quiescent current for linear operation, and has only a limited amount of negative feedback available to correct output stage distortions. Any deeper investigation would need to be encouraged by some promise that the Olsson configuration can deliver substantial benefits, and as far as my analysis goes, this does not seem likely. ■

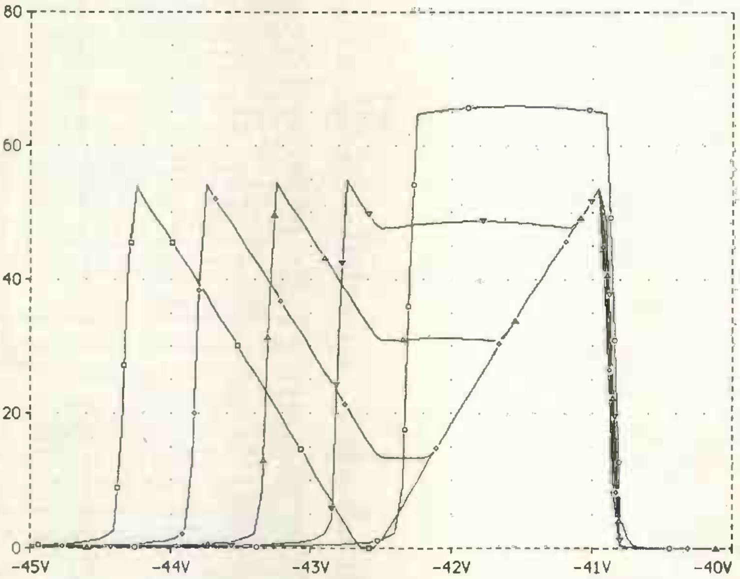


Fig. 5. Incremental gain plot for the Olsson stage, with V_{bias} stepped. The -AB mode (curve B) shows serious gain variations and therefore poor linearity.

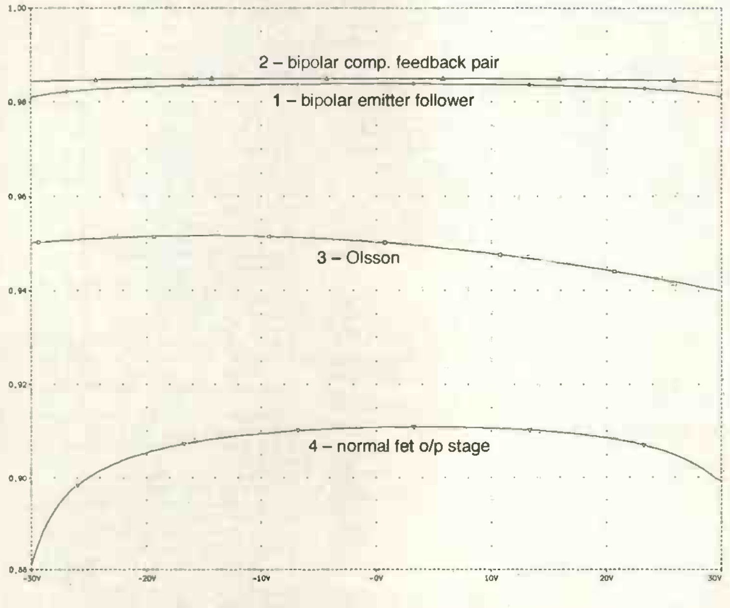


Fig. 6. Curve 3 shows incremental gain for the Olsson stage, driving 8Ω in Class-A. Equivalent plots for conventional Class-A bipolar emitter follower (curve 1), bipolar complementary feedback pair (curve 2) and a normal complementary fet stage (curve 4) are shown for comparison.

References

1. Olsson, B., 'Better audio from non-complements?' *EW+WW*, Dec. 1994 pp. 988-992.

2. Self, D, 'Distortion in power amplifiers: Pt 1' *EW+WW*, Aug. 1993.

3. Self, D, 'Distortion in power amplifiers: Pt 3' *EW+WW*, Oct. 1993.

4. Self, D, 'Distortion in power amplifiers: Pt 4' *EW+WW*, Nov. 1993.

5. Hood, J L, 'Simple Class-A amplifier.' *Wireless World*, Apr. 1969.

6. Self, D, 'Distortion in power amplifiers: Pt 7' *EW+WW*, Mar. 1994.

The latest update of the longest established pc-based circuit simulator now analyses mixed-mode designs, but was making *MicroCap V* compatible only with Windows also a step forward? Ben Duncan wonders.

Mixed-mode **modelling**

Previous generations of *MicroCAP* have had all the benefits of a 'windows-like' environment in dos. One of the keynotes of *MicroCAP-V*, or *MC5*, is that it is written in 32-bit code and runs under Windows. This brings the advantages of select-your-own typefaces, ease of screen grabbing, pasting simulation schematics and graphs into other programs. It also makes printer control more coherent.

However, it also has the penalty of needing 8MB of memory to run what only needed 4MB under dos. This is in additon to Windows' existing problems of flakey double click and an excessive reliance on mouse selection. There is also presently an incompatibility between Microsoft's own mouse and drivers and Win 32s. This driver upgrades Windows 3.1+ to 32 bits.

Another keynote is an event-driven digital logic engine. Using PSpice syntax, many users won't need to relearn anything. The promise of seamless digital/analog modelling seems a very good reason for buying *MC5*.

Digital features

Digital analysis is outside my domain, but I can outline the new version's essentials. *MicroCAP-5* has about 75% of the digital models in PSpice. Each program's libraries can be read by the other. PSpice can read *MC5* text circuit files or alternatively, *MC5* can read most PSpice files. Analogue and digital circuits can be freely mixed, either in *MC5* schematics or in Spice text file circuits.

> **System requirements**
>
> Windows 3.1 + optional Win 32s – when debugged – Absolute minimum 33MHz AT PC with 386-DX, dos 5, and 8Mbyte ram. However 16MB is recommended.

Digital nodes, like analogue ones, are numbered automatically and can be referenced by any legal name. On schematics they are in square boxes, whereas analogue node boxes are clearly distinguished by radiusing. Interfacing between analogue and digital nodes and *vice versa* can be automatic, with hard one, zero or fuzzier R, F, X levels.

To enable tri-state and multiple open-collector outputs to be accurately modelled, six digital states are allowed, each with different strengths and levels. Device input/output models provide impedance and switching time data. These determine output strength with wire-ORed parts.

Loading, inertial and transport delays are covered. Path commands identify and list gates in paths as well as calculating and showing each paths delay. They can be 'point-to-end', 'point-to-point' or 'show all paths'.

Delays can be minimum, typical, maximum, or the worst case minimum-maximum, creating a realistic ambiguity region. Equally, timing hazards, for example convergence or cumulative ambiguity hazards, can also be modelled.

Digital powering is automatically provided for a given logic family. There are over 1200 digital parts. Primitives include *pla*s and multibit d-to-a/a-to-d converters. Bistable devices may be both edge and level triggered, and gated latches similarly *srff* and *dltch* types. Digital stimuli can originate from a generator or a file. Generator form can create virtually any waveform.

Analogue developments

There is a number of small additions to the analogue features in the new version, mostly concerning analysis. Temperature modelling abilities of *MC5* – previously a relatively a weak spot – have since caught up with other high-end Spice-based programs. Now, *measured*, *absolute*, *local* and *global* temperature settings are all handled.

Unfortunately, *MC5* follows the obscure nomenclature of Spice. For example, the 'absolute' temperature would be

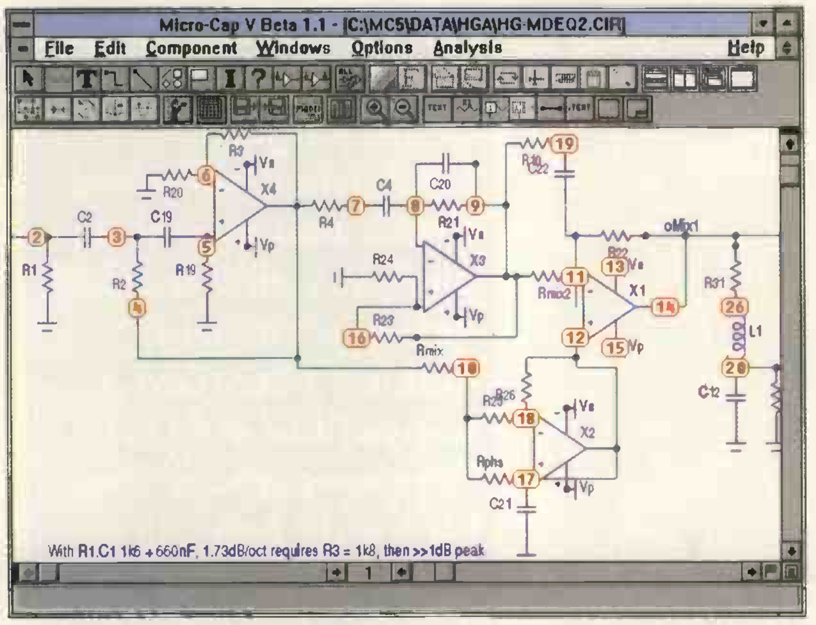


Fig. 1. Fragment of a filter system, converted from MC4. Only the psu macro – two batteries – had to be replaced to get it to run 'as was'. With the Beta copy tested, some text labels have shifted to overlap, but in any event, MC5 allows all part labels to be moved freely. Note the icons above the schematic and help screen below.

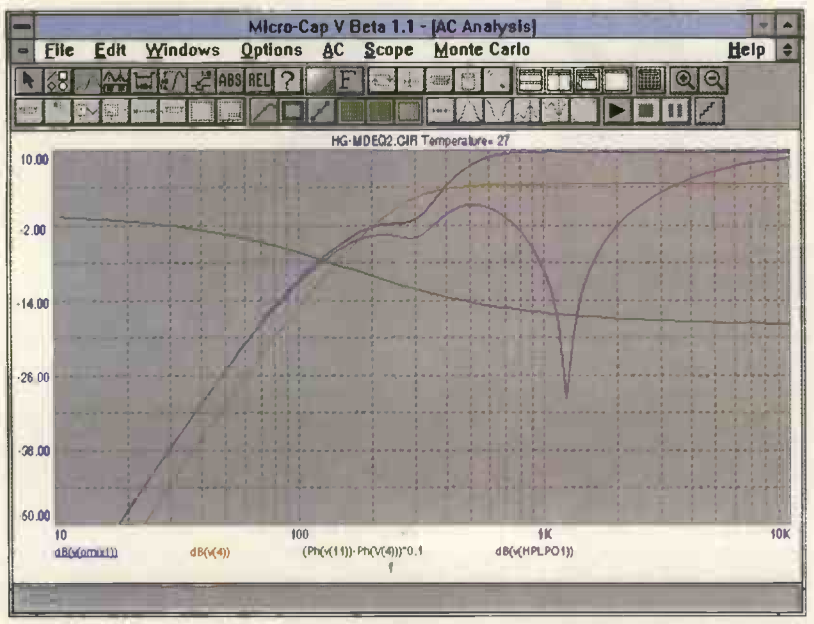


Fig. 2. An example of four simultaneous ac plots. Any mixture of ac operators may be employed, provided a common scale is realisable. Here the green graph is phase and the others are amplitude. Any number of plots are allowed in theory but there are only sixteen colour choices. The new cursor function is annotating the approximate 34dB difference between one plot and the dip of another.

better named a 'solo' temperature, as it is independent from the others, including the default global temperature. The 'measured' setting is not used in simulation. Instead it re-normalises spice parameters when measured at other than the fixed, nominal 27°C.

In stepping, it is now easier to enter model parameters like BF – as opposed to simple part values with enhanced control. With the default 'public' library, each part shares its model parameters with others using the same model name.

If, as before, you wanted to step one *BC337* transistor's β, among other *BC337*'s in your circuit, you would normally have to rename it 'Tr_3' or some other legal and previously unused name. However, using the 'private' option when initially drawing a schematic, only a given part's parameters are stepped.

With *MC5*, the only part that cannot now be stepped, excepting the various tabular sources, is the transformer. This can be replaced though through mutualled inductors which are steppable. When a relatively subtle parameter, say the 'vaf' of one transistor in many, is being stepped, a new command line enables it to be plotted on the analysis screen. This allows you to verify whether it is being stepped or Monte-Carlo processed.

After analysis, cursors can now provide approximate auto measurement on the screen between any pair of horizontal or vertical data points, Fig. 2. To ensure multiplot clarity in black and white printouts, six types of graphic primitives can be placed on the graph, for instance a diamond.

When analysing, any number of simultaneous plots can now in theory be specified. This can have its creative uses such as mass parallel plotting of circuit alternatives. Reviewing the beta software version I could only get four plot colours to run, Fig. 2, but readers can rely on Spectrum Software meeting their specification on release.

Inductor and core modelling has been changed from using a 'mutual' statement to the spice format, using the 'K' device. This is straightforward – core data as *MC4*, with turns as the inductor parameter.*Micro-CAP* and PSpice appear to be the only pc simulators using the advanced Jiles-Atherton magnetics model.

In the model editor I found a 'revert' function, something every good program should have. In the event of a data entry disaster it puts everything back to where it was at the start of a session.The manual continues in the *MicroCAP* tradition of being unusually well written, if somewhat terse. It contains a useful chapter on solving bad convergence. If *MC5* runs like its predecessor then this chapter will not be needed often.

Reliable and fuss-free conversion of the tens of thousands of *MC4* files to the *MC5* format is vital. I tested a variety of different circuits and found this was the case with just one exception – all macros had to be partly re-created manually. *MC4* macros should not need re-creating in the released version – a 'merge' command should auto-convert them. This is something of a nuisance, especially, if like me you have dozens of standard macros, such as a psu that appears in nearly every schematic needing conversion. Still, it is far better than having to convert parts of thousands of *MC4* files individually.

The first version *MicroCAP* appeared 14 years ago, making this package the longest surviving pc simulator. It is also the most friendly of the £1k-£10k packages as far as it is 100% seamless – compared with similarly costly pc simulators that comprise a Spice core with a schematic editor and other functions bolted on as an afterthought.

For the intuitive user, *MC5* largely avoids the counter-intuitive jargon of spice-land. A battery is called a battery. ■

Software sourcing

Manufacturer – Spectrum Software, 1021 S.Wolfe Rd, Sunnyvale, CA 94086, USA. UK distributors, Rainbow Software, phone or fax 0181 295 4500, Datech, 0181 308 1800, fax 308 0802. A demonstration disk is available.

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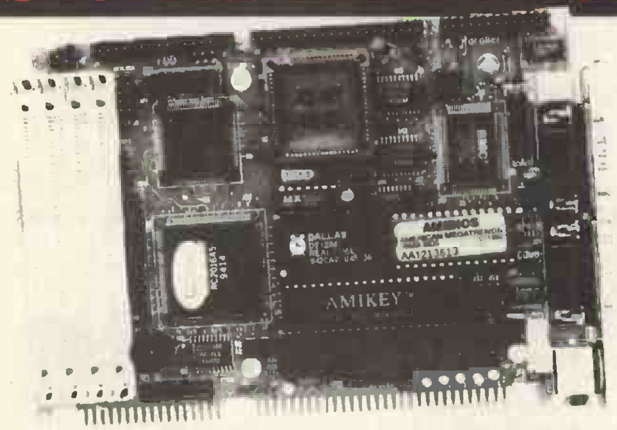

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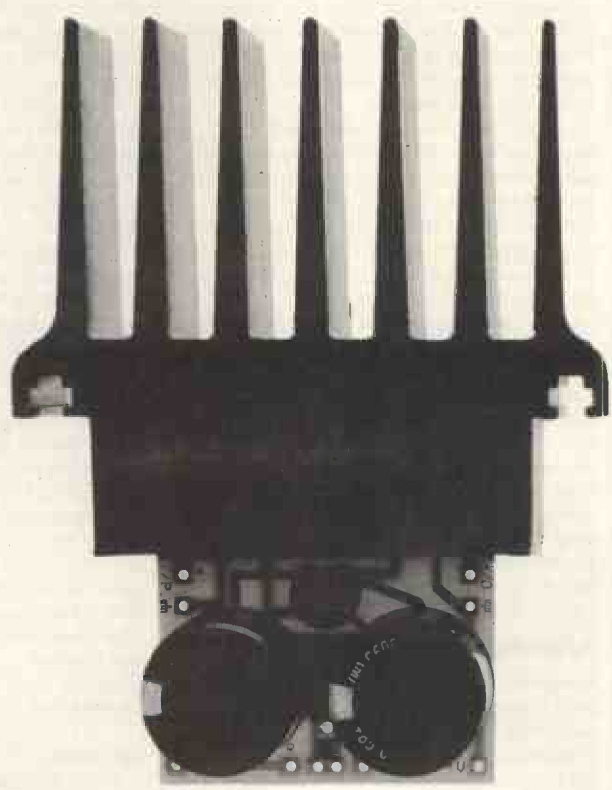


OLP DIRECT

CIRCLE NO. 128 ON REPLY CARD

LETTERS

Letters to *"Electronics World"* Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Earth grounds for digital tv

Your editorial in the July edition debating the pros and cons of various means of digital television delivery was stimulating as usual.

Digital television may well be available first via satellite and cable systems, but we are of the view that digital terrestrial television still has a major part to play – particularly for universal service and the delivery of regional and local services, and for tv sets where access to satellite or cable is either inconvenient or impossible.

Your assertion that "there is absolutely no reason to run digital tv from land based transmitters" is a conclusion with which we could not agree. Estimates for the percentage of population able to erect antennas and receive satellite television services directly vary between 80-95%, depending on source.

It ought to be easy to accept that not every home in the country can erect a dish in a suitable position. As a result, it is impossible for geostationary satellites ever to achieve the 99.5% penetration of the current analogue services. There are also planning constraints on the erection of dishes which might well apply even to the smaller dishes that will most probably be practicable for digital satellite tv.

The benefits of digital terrestrial are that it can reach houses other technologies cannot reach; that it provides a more attractive route for local and regional television; and that if early tests prove correct, it can deliver a robust service to set top aerials for portable reception and second and third sets in the home which do not have access to the main satellite/cable delivery point.

Your point about the amount of spectrum occupied by television broadcasting is well made, but I suspect few of your readers would be enthusiastic if we were to relocate domestic television to an alternative slot in the spectrum at short notice and everyone had to buy converter boxes or new televisions and a new aerial.

However, our long strategy is to free up a portion of the spectrum currently used for terrestrial television broadcasting for other applications. This might include mobile tv which opens up another

Speakers and dynamos, mismatching and reluctance

In the May issue, Jeff Macaulay remarked that moving-coil loudspeakers are somewhat crass devices that lose 99% of the applied energy in copper losses. In the June issue a correspondent complained that his cycle dynamo achieved constant output by being very inefficient.

Both are wrong. Loudspeakers are lossy mainly because of the mismatch between the cone and the surrounding air, which of course can be changed by the use of a horn, which makes efficiency is much higher.

As a permanent-magnet alternator, the cycle dynamo suffers from the field generated by the rotor when a lagging current is drawn. This current bucks the voltage generated in the way a series inductance would.

In power engineering, the equivalent inductance is called synchronous reactance. You cannot design it out. I reckon if you short circuit the machine at any speed, it will circulate sufficient current internally to nul the internal magnetic field at its peaks. But this current will be the same regardless of speed, except that the idea must fail at some low speed.

So you have something akin to a constant-current machine operating over a range of speeds. Bulbs in the circuit are constant-current devices too, so if they have different ideas about the magnitude of the current, problems occur. As a result, if I manufactured cycle dynamos I would try to obtain a precisely defined output from them.

In the interests of better lighting, I think manufacturers should produce a large dynamo.

Bernard Jones,
London

Alternate dynamo

In response to Steve Bush's letter in the June issue concerning bicycle dynamos, I would like to pass on the results of my research.

The bicycle dynamo is not a dynamo at all, since a dynamo is a dc machine. It is actually a single-phase alternator.[1,2] Electrically it looks like an ac voltage source whose voltage and frequency are linearly proportional to speed; in series with the resistance and inductance of the windings.

A motor vehicle alternator has a field winding whose current can be varied to vary the magnetic field, and thus the output. The cycle dynamo on the other hand has a permanent magnet, and cannot be regulated. At high speeds, the inductance dominates. As its reactance is also linearly proportional to speed, the output is a crude constant current source. This is as close to regulation as it can manage. Unloaded ac output can exceed 100V rms.

In order to extract maximum power, the dynamo must be run at the lowest possible current. Additionally, advantage must be taken of the high unloaded output voltage. Rectification schemes that take large, short current pulses such as a simple diode and capacitor will not work however. This is due to the inductance limiting dI/dt.

A power factor corrector IC may be worth trying. In simple terms, a higher power output ought to be possible by using a higher voltage lamp with the same current rating as the original, at the expense of reduced brightness at lower speed.

Cycle lamps seem to manage an efficiency of about 5 lumens per watt. Leds vary from about 1lm/W to 30lm/W, but are usually quoted in candelas. Convert to lumens by multiplying by $2\pi(1-\cos\phi)$ where ϕ is the half angle of the output beam.

Rear lamp red leds capable of out-performing the filament lamp are reasonably common, but yellow leds for front lights are not.There are a few ultra-bright yellow types available from Hewlett-Packard (RS 826-723 and 823-717).

Filament-lamp brightness is proportional to the cube of applied voltage, current to the square root, and life inversely to the twelfth power,[3] but longer for an ac supply. Lower voltage lamps have thicker filaments, and therefore better mechanical shock resistance.

Ian Benton
Ilkeston
Derbyshire

References

1. Smith, RJ, 'Circuits, Devices and Systems', Chapter 4, ISBN 0-471-80516-5
2. Admiralty 'Examples in Electrical Calculations', Chapter 24, HMSO B.R.158
3. Oshino Lamps catalogue

Steve replies...

I agree with both correspondents that dynamos are simple constant-current ac machines, but I suspect the laminations of the stator are deliberately thick to reduce output voltage by increasing eddy currents at high speed. This technique is certainly used in the alternators of cheap motorcycles.

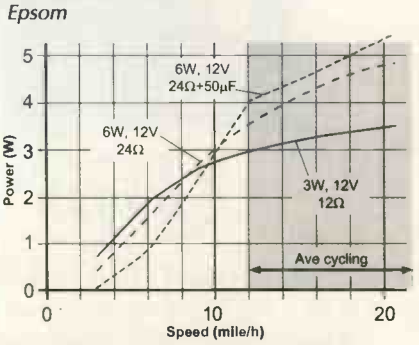
Using higher voltage bulbs does therefore work, but the physical effort required to produce a certain power output is disproportionally large. After a few lunch times wrestling with a propped-up bike, a handful of dynamos and an AVO, I have determined the following:

- A series capacitance in the circuit increases the output, probably by series resonance with the dynamo inductance. Selection of the value can produce an extra watt.
- No cycle dynamo has magnetics that are efficient enough to produce 6W without unacceptable physical effort – whatever electronics are fitted.

The next step is to try a different machine, perhaps a rare-earth, three-phase brushless dc motor, which should look like a 'star' wound generator (has anyone got one that I can experiment with?).

Note that 12Ω is the standard load used in BS bicycle specifications.

Steve bush,
Epsom



Output versus loading for a Soubitez dynamo. British Standard loading is 12Ω but 24Ω with a series capacitor produced better results. Plots were produced using an average reading ac voltmeter so there will be some errors due to distortion of the waveforms involved.

hornet's nest of diverging views about the benefits, practicability and desirability of mobile television!
Adrian Grilli,
Director of Broadcasting Services, Radiocommunications Agency, London

Give them a chance

Frank Ogden's leader Jobs for the Boys (July 1995) was, as usual, a model of clear prose – reasonably factual with an unmistakable conclusion. Regrettably that conclusion was wholly wrong.

Lord Thomson, when he chaired the IBA, argued in its latter days for "change with continuity" in broadcasting. That was in the late eighties when the ITV system was due for radical overhaul and the IBA, itself about to be disbanded.

My union BECTU, which represents all broadcasting, film and theatre categories, including NTL and BBC transmission staff, agrees that continuity is a vitally necessary concomitant of change. The existing terrestrial transmission networks should provide that continuity between analogue and digital transmission, for the sake of viewers, listeners and programme makers.

Satellite and cable delivery are playing an increasing role. However it is clear that neither separately nor together can they soon replace terrestrial transmission – if ever.

That durable and reliable system, comprising the hundreds of sites owned by BBC, and NTL, and importantly operated by highly trained and qualified engineering staff will remain the main delivery system for decades to come.

To deny BBC and NTL any role in digital broadcasting would be both wrong and shortsighted. Both organisations are developing commercial activity in telecommunications. If their core businesses of television and radio transmission were restricted both would be hard pressed to maintain and grow those increasingly important sectors.

Do not hasten the end of BBC and NTL – they both have an important role still to play.
Brian Marsh,
National Organiser BECTU

Emi *still* not understood...

Dr Walton's letter, EMI Still Not Understood, *EW+WW*, July 1995, took its theme from a newspaper article which contained unsubstantiated statements. I would therefore like to take this opportunity of putting the record straight and allaying Dr Walton's concerns.

Aviation authorities and industry have, for many years, recognised that aircraft and their systems need to be protected against the effects of electro magnetic interference, EMI. Sources of EMI generated within the aircraft can be non-intentional or intentional as in the case of the aircraft:'s own high power communication transmitters. The required protection is demonstrated by ensuring that aircraft and their systems are qualified to electro magnetic compatibility, EMC, standards appropriate to aviation operations. These standards, which were written in conjunction with aviation industry experts, have been continuously updated as the level of understanding of EMC and the possibility and consequences of EMI have increased. As a result of the application of these standards, aircraft and their systems have continued to demonstrate a high level of immunity to EMI.

The issue of interference to aircraft systems by portable electronic devices, PEDs, is one which it is correct to become concerned about. There have been a number of reports of interference with aircraft navigation systems (but not with flight critical systems as inferred in the newspaper article), which were investigated but could not be substantiated. For this reason, aviation authorities have adopted a cautious approach and many have imposed a ban on the use of PEDs during certain phases of flight. However, they are not content with such a simplistic approach and are current]y researching the issue to determine if PEDs are capable of emitting sufficient power to cause airborne system disruption and how any electromagnetic coupling between PEDs and airborne systems could occur.

In the same way that airborne inter/intra-system EMC issues have been recognised as a potential problem, so has lightning. To this end, aviation authorities also require that aircraft and their systems demonstrate immunity to the effects of electromagnetic energy generated

Seeking failure

Can anyone help? I am researching the cause and consequences of equipment failure and I am interested in hearing from readers who have first hand knowledge of specific instances. I would like any failure details of electronics, mechanisms, structures, software or procedures.

Photographs, reports etc would be much appreciated particularly if the failure resulted in serious mishap which might have been avoided.

All letters will be acknowledged.
Bob Collins, 1 Church Street, The Square, Wimborne Minster, Dorset BH21 1JH.

by lightning. Again, these requirements are written against aviation industry standards.

Considering the issue of how airborne systems withstand the electromagnetic 'explosion' of lightning but not the electromagnetic 'whisper' of PEDs, remember that the 'explosion' takes place outside of the Faraday cage provided by the aircraft fuselage.

With regard to the possibility of terrorist attack, modern aircraft and their systems are even now under 'attack' by high power external rf sources such as commercial broadcast transmitters, satellite communication transmitters and surveillance radars, which generate very high electromagnetic fields. Again, aviation authorities have recognised this problem and, in conjunction with aviation industry experts, have developed design and test criteria for aircraft and their systems to ensure they remain immune to such rf illuminations. These design and certification criteria should also ensure the immunity of flight critical systems to potential terrorist activity, be it generated by an on-board suicide 'emitter', or a source outside the aircraft.

C F.Phelan
Head of Avionics and Electrical Systems Group, CAA

...nor are analogue systems

Dr David Walton writing about the laptop computer ban in airplanes (Letters, July issue) may well be an expert on digital systems and the electromagnetic compatibility rules needed to make those systems work safely. But he is not aware of the analogue systems used in avionics.

Radio beacons and instrument landing systems (ILS) are analogue. They rely on fixed land-based transmitters continuously sending waves – on clean channels – to airborne receivers.

These waves are modulated and/or beam-formed so that airplanes using directional antennas and/or discriminating detectors can find their way safely towards the next beacon. In the axis of the landing runway the safe glide path for touching down on the right spot of the runway can be found. This allows manoeuvres to start many miles away from beacons through heavy clouds or fog.

Lightning interference may well hide such weak oncoming vhf radio waves, but only for very short durations. Proper operation relies on continuous heading or path searching and keeping, except during lightning pulses. A lightning pulse cannot set any data bit. It is an insignificant transient type of interference which can be filtered out at any step in the process.

Most terrorists do not want to be inside the airplane they want to destroy. They also want a reliable means of destroying an airplane, which is not simple. A jammer near an airport would have to be on the right frequency, which is easy. But in order to go unnoticed long enough to lead an airplane to a crash, the transmitter also needs to radiate the right power with the right antenna beams – very unlikely.

Conversely, weak but continuous interference – any harmonic of a local oscillator or computer clock for example – from aboard the airplane can impair the operation of the ILS, if this interference is within the radio channel. The problem is especially acute when the signal is radiated by whip antenna or mouse cord. Under worst-case conditions, the interference goes unnoticed, but the instrument on the dashboard gives continuous false bearing or glide angle that can result in collision or crash.

So the best way to prevent terrorist attacks against ILS is still the ban of computers, radios, etc in airplanes.

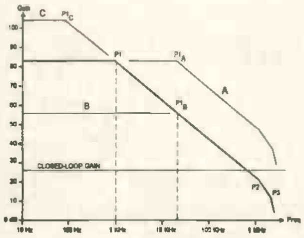
Louis Aubree,
Nantes,
France

Self reacting

I must admit I was disappointed in Ivor Brown's example of negative feedback operation (Letters, June 95) as it seems likely to add to the confusion that exists in some minds between open-loop bandwidth and slew rate. He says "limited open-loop bandwidth prevents the feedback signal from immediately following the system input." This is not true unless the amplifier has been pushed into slew-limit.

No linear circuit can introduce a pure-time delay; the output must begin to respond at once, even if it takes a long time to respond fully. In the typical amplifier the dominant pole capacitor introduces a 90° phase shift between input pair and output at all but the lowest frequencies; this is not in any way the same thing as a time delay. The phrase "delayed feedback" is sometimes used to describe this situation, and it is a wretchedly inaccurate term; if you really delay feedback to a power amplifier, it will turn into the proverbial power oscillator as sure as night follows day.

I agree with ivor that the amount of negative feedback applied should be maximised at all audio frequencies, and to my mind the only limit on this is the requirement for hf stability; the point at issue is how to go about it.



Open and closed-loop gain for a typical generic power amplifier with closed-loop gain set at 26dB.

The heavy line in the diagram shows the open and closed-loop gain for a typical generic amplifier; closed-loop gain is set at +26dB as usual. The second and third poles P2 & 3 are just beyond the intersection of the two gain lines, so the curves close on each other at no more than 6dB/octave and Nyquist stability is obtained. Dominant pole P1 is a 1kHz. Below this frequency the open-loop gain curve levels out the feedback factor becomes constant.

So, supposing we want to increase the negative feedback to a maximum. What can be done? Clearly, if our target is a constant negative feedback factor across the audio band, which appears superficially attractive, the P1 must be increased to 20kHz, and we can claim 'high open-loop bandwidth'. This can be done in two ways: firstly we can increase the open-loop gain at hf by decreasing the compensation capacitor so that we get curve A with P1A at 20kHz; but this also lifts P2 & 3 above the unity loop-gain level and we get a power oscillator and the tweeters explode.

Alternatively we can reduce the open-loop gain at low frequencies, by shunting the compensation capacitor with a resistor, giving curve B with P1B at 20kHz once more. This will be stable, and may look nice on a graph, but seriously reduces the amount of feedback at low frequencies, gives much more distortion than necessary, and badly degrades ripple rejection.[1] Neither A nor B is acceptable.

I hold that the amount of feedback should be truly maximised, as said before. The open-loop gain is therefore left alone in the falling 6dB/octave region, where it is already maximal if we stick to this slope. Instead the flat low-frequency region is raised to give curve C, which has a lot more negative feedback at low frequencies than the original. This is simply done either by cascoding or adding a beta-enhancing emitter-follower to the voltage amplifier stage[1] This in turn pushes the new dominant pole P1C down to a much lower frequency, possibly as low as sub-10Hz, but so what? We have only altered linear gains in various parts of the circuit, and have not affected the non-linear limit phenomenon of slew rate at all. I have calculated this, simulated it, measured it and even built a special amplifier where P1 could be varied with a knob on the front panel, so I'm pretty sure of my ground here.

The only way to increase the amount of negative feedback applied above that shown in curve C is to make the compensation more complex, so that we are not confined to a 6dB/octave gain roll-off. In the form of two-pole compensation in the second reference, the gain is held constant up to a higher frequency, before rolling off more quickly; the key to stability is that the slope reduces to 6dB/octave before the Nyquist gain intersection is reached.

To say it once more; open-loop bandwidth and slew rate are nothing to do with each other. High-gain op-amps with sub-1Hz bandwidths and blindingly fast slewing are as common as the grass (if somewhat less cheap) and if that doesn't demonstrate the point beyond doubt then I really don't know what will.

In his letter Ivor also stigmatises sinewaves as steady-state' signals, which is presumably meant to imply that they are in some way particularly easy for an amplifier to handle. Since sinewaves have an unending series of non-zero differentials, 'steady' hardly comes into it. I know of no evidence that sinewaves of randomly varying amplitude would provide a more searching test of amplifier competence.

I think this view must be the result of anthropomorphic thinking about amplifiers; twenty sinewaves of different frequencies may be conceptually more complex to us, but to an amplifier it resolves to a single instantaneous voltage that must be increased in amplitude. An amplitude. An amplifier has no perspective on the signal arriving at its input, but must take it as it comes; one might also say, 'the amplifier has no memory' by analogy with the roulette wheel.

To remind us that a distortion analyser is incapable of distinguishing between Bartok and Bon Jovi is not really necessary; why ever should it mimic the human brain? I don't want a machine to enjoy music for me so that I don't have to do it... ■

1. Self, D, 'Distortion off the rails' *EW+WW* Mar 1995, p210
2. Self, D, 'Distortion in Power amplifiers' *EW+WW* Feb 1994, p140.

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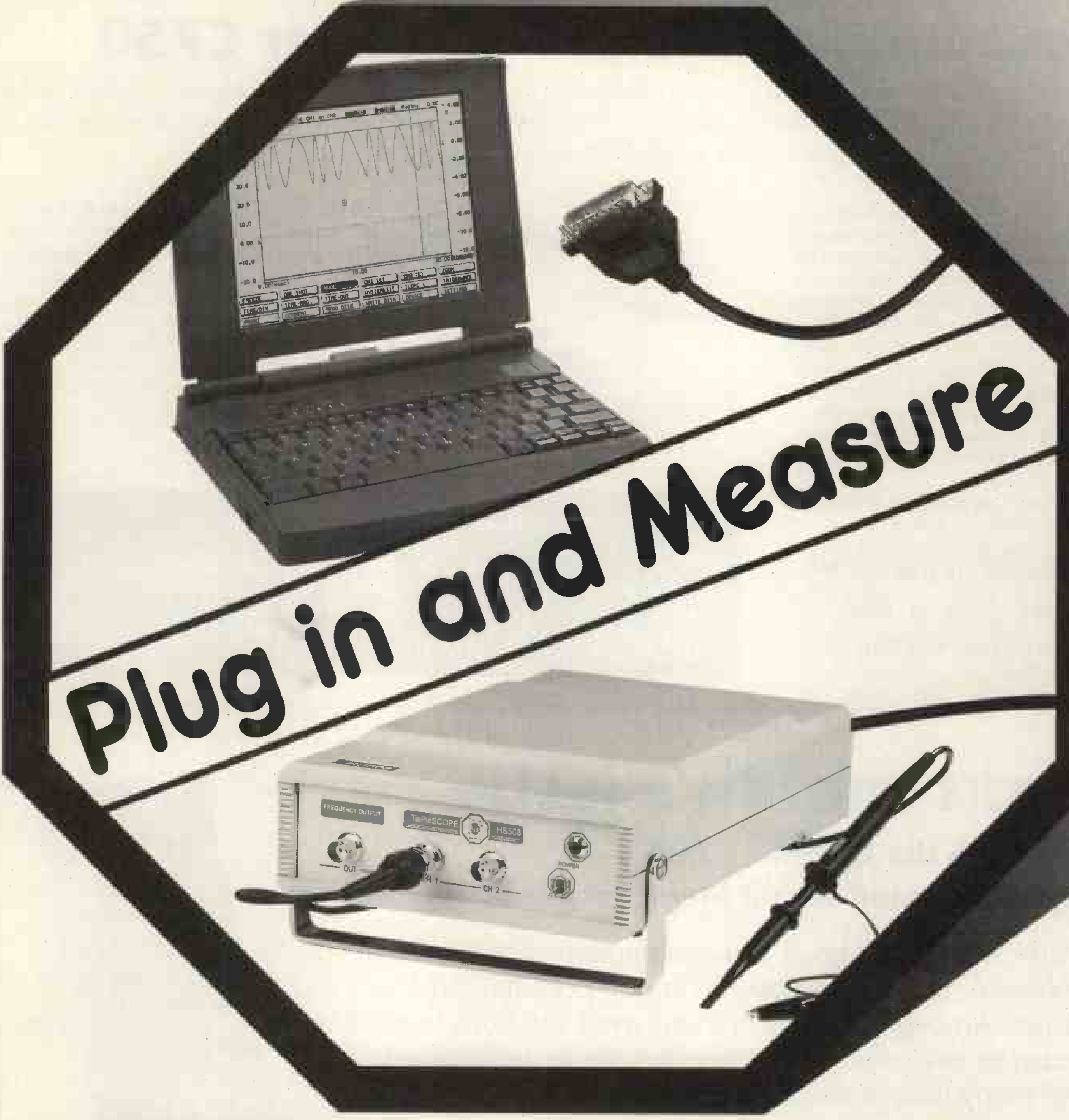

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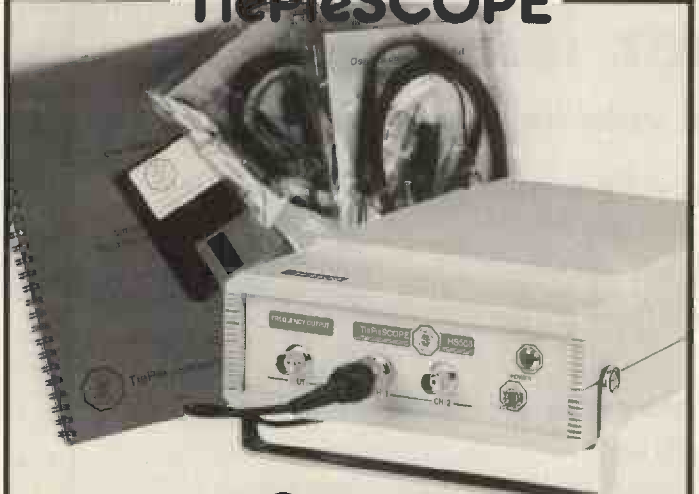

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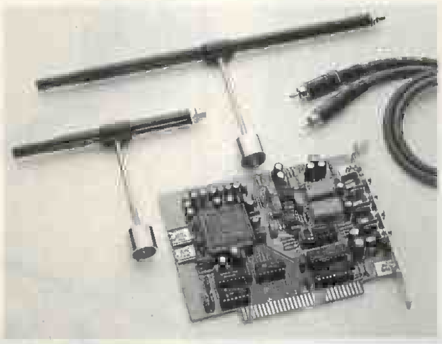
Reviewed in *EW+WW*, August 1995, p. 656 'AF analysis via the pc'



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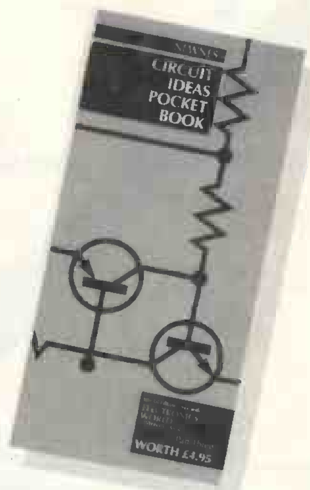

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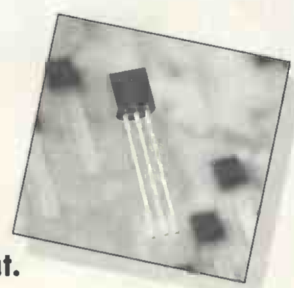

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HP 8160A 50Mc/s programmable pulse generator – £1000.
HP 853A MF ANZ – £1.5k.
HP 8349A Microwave Amp 2 – 20GHz Solid state – £1500
HP 3585A Analyser 20Hz – 40Mc/s – £4k.
HP 8569B Analyser .01 – 22GHz – £5k.
HP 3580A Analyser 5Hz – 50kHz – £1k.
HP 1980B Oscilloscope measurement system – £600.
HP 3455A Digital voltmeter – £500.
HP 3437A System voltmeter – £300.
HP 3581C Selective voltmeter – £250.
HP 5370A Universal time interval counter – £450.
HP 5335A Universal counter – 200Mc/s – £500.
HP 5328A Universal counter – 500Mc/s – £250.
HP 6034A System power supply – 0 – 60V – 0 – 10 amps – £500.
HP 5150A Thermal printer – £250.
HP 1645A Data error analyser – £150.
HP 4437A Attenuator – £150.
HP 3717A 70Mc/s modulator – £400.
HP 3710A – 3715A – 3716A – 3702B – 3703B – 3705A – 3711A – 3791B – 3712A – 3793B microwave link analyser – P.O.R.
HP 3730A+B RF down converter – P.O.R.
HP 3552A Transmission test set – £400.
HP 3763A Error detector – £500.
HP 3764A Digital transmission analyser – £600.
HP 3770A Amp delay distortion analyser – £400.
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HP 3781A Pattern generator – £400.
HP 3781B Pattern generator (bell) – £300.
HP 3782A Error detector – £400.
HP 3782B Error detector (bell) – £300.
HP 3785A Jitter generator + receiver – £750-£1k.
HP 8006A Word generator – £100-£150.
HP 8016A Word generator – £250.
HP 8170A Logic pattern generator – £500.
HP 59401A Bus system analyser – £350.
HP 59500A Multiprogrammer HP – IB – £300.
Philips PM5390 RF syn – 0.1 – 1GHz – AM + FM – £1000.
S.A. Spectral Dynamics SD345 spectrascope 111 – LF ANZ – £1500.
Tektronix R7912 Transient waveform digitizer – programmable – £400.
Tektronix TR503 + TM503 tracking generator 0.1 – 1.8GHz – £1k – or TR502.
Tektronix 576 Curve tracer + adaptors – £900.
Tektronix 577 Curve tracer + adaptors – £900.
Tektronix 1502/1503 TDR cable test set – £1000.
Tektronix AM503 Current probe + TM501 m/frame – £1000.
Tektronix SC501 – SC502 – SC503 – SC504 oscilloscopes – £75-£350.
Tektronix 465 – 465B – 475 – 2213A – 2215 – 2225 – 2235 – 2245 – 2246 – £250-£1000.
Kikusui 100Mc/s Oscilloscope COS6100M – £350.
Nicolet 3091 LF oscilloscope – £400.
Racal 1991 – 1992 – 1988 – 1300Mc/s counters – £500-£900.
Fluke 80K-40 High voltage probe in case – BN – £100.
Racal Recorders – Store 4 – 4D – 7 – 14 channels in stock – £250 – £500.
Racal Store Horse Recorder & control – £400-£750 Tested.
EIP 545 microwave18GHz counter – £1200.
Fluke 510A AC ref standard – 400Hz – £200.
Fluke 355A DC voltage standard – £300.
Wiltron 610D Sweep Generator + 6124C PI – 4 – 8GHz – £400.
Wiltron 610D Sweep Generator + 61084D PI – 1Mc/s – 1500Mc/s – £500.
Time Electronics 9814 Voltage calibrator – £750.
Time Electronics 9811 Programmable resistance – £600.
Time Electronics 2004 D.C. voltage standard – £1000.
HP 8699B Sweep PI YIG oscillator .01 – 4GHz – £300. 8690B MF – £250. Both £500.
Schlumberger 1250 Frequency response ANZ – £1500.
Dummy Loads & power att up to 2.5 kilowatts FX up to 18GHz – microwave parts new and ex equipt – relays – attenuators – switches – waveguides – Yigs – SMA – APC7 plugs – adaptors.
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W&G Items in stock – ask for list.
Power Supplies Heavy duty + bench in stock – Farnell – HP – Weir – Thurlby – Racal etc. Ask for list.

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CIRCLE NO. 144 ON REPLY CARD

Predicting fm NOISE effects

Everyone knows that noise affects integrity in fm data communications – but by how much? Simon Day discusses the problem.

Why fm? Frequency modulation, carrying data, audio or television, is very popular. Its advantages are,

- bandwidth is controlled simply by adjusting deviation to set spectral occupancy. A minimum of twice the highest baseband modulating frequency is needed.

- constant envelope – no amplitude component – means a linear transmitter is unnecessary; frequency multipliers can be used with no distortion to the signal. Carrier harmonics must be filtered out in the usual way.

- hardware implementation is straight forward. Only amplitude modulation with super-regenerative demodulation provides a simpler option.

Noise level is independent of deviation. As a result, signal-to-noise ratio can be improved arbitarily by simply increasing deviation, and hence the signal level in the numerator of the s-n ratio. Limits to this are firstly regulatory.

Increased deviation widens occupied rf bandwidth according to Carsons's rule (of thumb), which gives bandwidth as twice highest modulating frequency plus the peak to peak deviation.

In the UK, the Radiocommunications Agency – part of the DTI – issues performance specifications called 'MPTs'. These include limits of adjacent channel power, spectral occupancy etc. In principle, increasing deviation will incur a greater cost as rf spectrum is auctioned off.

Secondly as deviation is increased a technical difficulty arises; the threshold effect destroys the integrity of the fm system and no useful output is produced. The margin above threshold is an important operational system parameter.

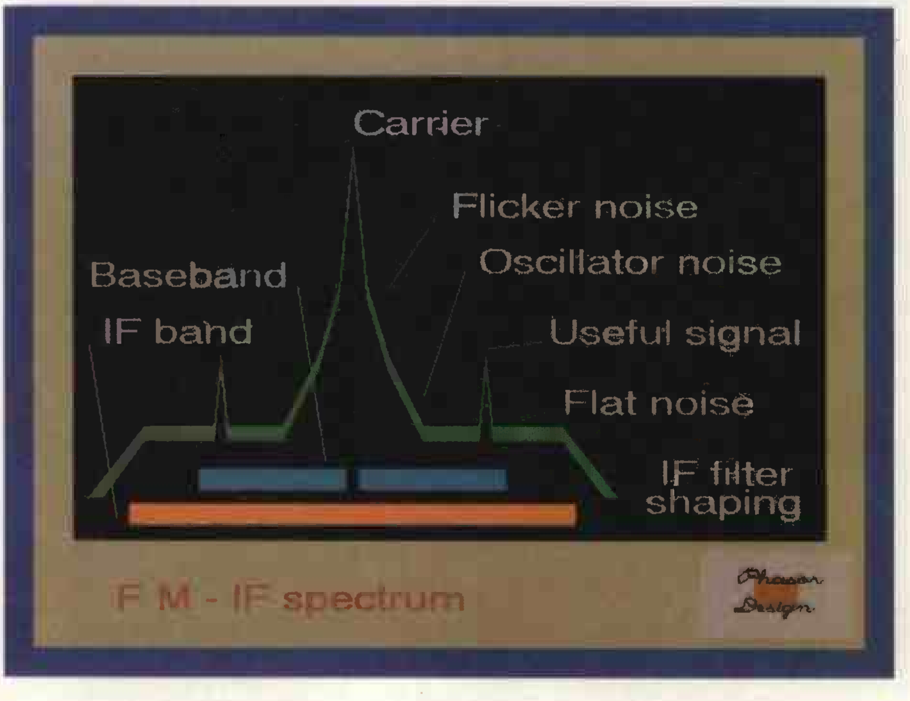
Improving performance

With deviation set according to the criteria above, the system quality – s-to-n ratio – can only be improved by reducing the noise level.

Many factors contribute, including received carrier level, the noise figure of the receiver rf front end, baseband filtering after demodulation and transmitter modulator residual fm, i.e. ssb phase noise. De-emphasis and local oscillator residual fm also play a role.

A key reciever parameter, which does not affect noise level directly, is receiver IF

Fig. 1. This fm-if spectrum of carrier entering a demodulator shows that components far away from the carrier are removed by baseband filtering.



Software availability

FM Noise Analysis is available from Phasor Design at 16 Blenheim Way, Market Harborough, Leicestershire LE16 7LQ. Tel. 01858 432148, fax 432109. It is priced at £119 excluding VAT.

bandwth when above threshold.

Two additional factors relate to the measurement of noise. In audio and video systems, standard weighting networks are used. These modify the noise frequency distribution to represent the way noise is perceived by the ear or eye. The weighting networks may have gain so actually increasing the noise level. Mainly, rms detection is used to meter noise; audio systems are an exception, where average reading detection was promoted by Dolby Laboratories. This seems to have been accepted for domestic equipment; broadcast and professional noise measurements often use the CCIR 468-4 quasi-peak method which is accepted as reading about 5dB higher then rms.

Modelling noise

Fundamentally noise arises because the pure carrier becomes embedded in unwanted elements. These are resolved by the fm demodulator as baseband voltages. These elements are either noise sidebands originating in oscillators or 'link noise' caused by the carrier falling to the noise floor. **Figure 1** shows the situation entering the demodulator.

An important difference between oscillator and link noise – not visible in the IF spectrum – is the coherence between lower and upper sidebands. Most oscillators have little amplitude modulation noise so coherence exists. Link noise has no coherence and so half of this noise power is rejected by the fm receiver which is insensitive to amplitude modulation.

A geometrical representation of one noise element is illustrated in **Fig. 2.** The claim that IF bandwidth is not a factor above threshold is supported by Fig. 1 – the IF spectrum – which shows the noise components far away from the carrier are removed by baseband filtering.

CAD tools

A pc application called *FM Noise Analysis* from Phasor Design brings all these points together to predict s-to-n ratio in real systems. **Figure 3** is the graphical output forming a detailed simulation of the spectrum analyser connected to the receiver output.

FM system deficiencies can be quickly resolved by comparing experimental and predicted spectra. Signal-to-noise ratio is calculated by numerical integration and displayed, along with probability of a bit error for an fsk system.

A typical satellite television simulation is shown in **Fig. 3**; emphasis to CCIR Rec.405 for system I, and 200ns weighting are included along with transmitter and receiver oscillator noise contributions.

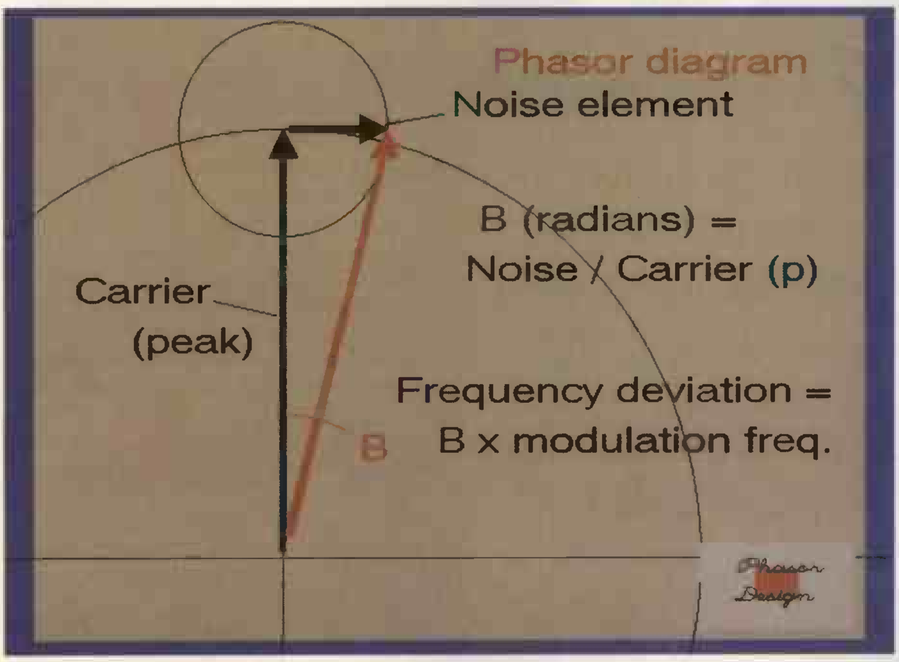
FM Noise Analysis is a software tool specifically developed to help engineers get the best from fm systems. Its design philosophy is to minimise learning time and provide a direct and clear way for the engineer to simulate and verify the noise performance of their communications system. It is based on actual engineering experience of optimising frequency modulated systems operating between 1MHz and 18GHz. ■

PC requirements

PC with 640K main memory
Dos 3.1 or higher
Printer port (for software key)
In addition, VGA monitor with colour printer are recommended.

Fig. 2. Phasor diagram – geometrical representation of a noise element, top photo.

Fig. 3. Graphical output of the spectrum analyser connected to a receiver output – part of a typical satellite-television simulation.



Asp and filtering

Continuing his review of analogue signal-processing techniques, Ian Hickman looks at filters and allows digits to make their appearance.

If preservation of the detailed shape of the wanted waveform is important, then some care in choice of filter type is important.

Low-pass. For any given order of filter, a Butterworth type gives faster cutoff above the pass-band than a Bessel filter, but it causes ringing on a pulse type of waveform. **Figure 1a)** compares the response of eight-pole Bessel and Butterworth filters, both with a 10kHz cut-off frequency, to a 3kHz square-wave input.

High-pass. These can improve the wanted signal-to-noise ratio in the same way as low-pass filters; for example, to reject mains hum, and its harmonics also, if a higher cut-off frequency is acceptable. However, whereas a suitable low-pass filter type such as Bessel will not cause any ringing or overshoot on a square wave or step function, overshoot seems to be an inherent feature of all high-pass filters of order higher than the first.

Figure **1b)** shows a high-pass *CR* circuit with a step-function input applied, giving the well known decaying output, down to just 37% (100/*e*) of the input after a time interval equal to *CR* seconds. A series of similar sections are cascaded after the first, giving a high-pass filter with five coincident poles on the real (negative) axis. This is not a good filter design, having an even 'softer' cut-off than a five-pole Bessel, being 15dB down at the 'cut-off' frequency of $f_c=1/(2\pi CR)$, but it aptly illustrates the point.

Figure 1c) shows the response at the output of each stage. As, initially, the input to the second stage is positive, its output decays towards zero, opening up an increasing gap between second stage input and output voltages, as shown. When the output voltage of the second stage reaches zero, its input voltage is still falling, causing the output voltage to reverse sign, eventually dying away to zero from below the axis.

A similar argument applies to the third stage except that, as the second stage output finally dies away from a negative value, the third stage output is pushed back across the baseline, dying away from a smaller positive value. If Fig. 1c) were replotted to an expanded vertical, it would be more easily seen that the *n*th stage output crosses the zero voltage baseline (n–1) times.

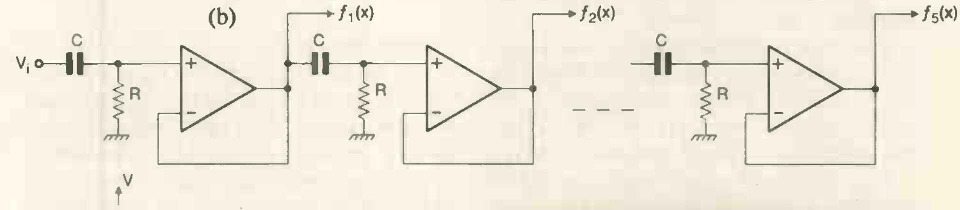
Coincident-pole high-pass filter are minimum-phase types, but if you go to a non-minimum phase design, you can have a high-pass filter with a squarer, sharper cut-off than Bessel, but still with constant group delay. Such filters were originally designed for band-pass applications[1], but the design was extended to high-pass types[2].

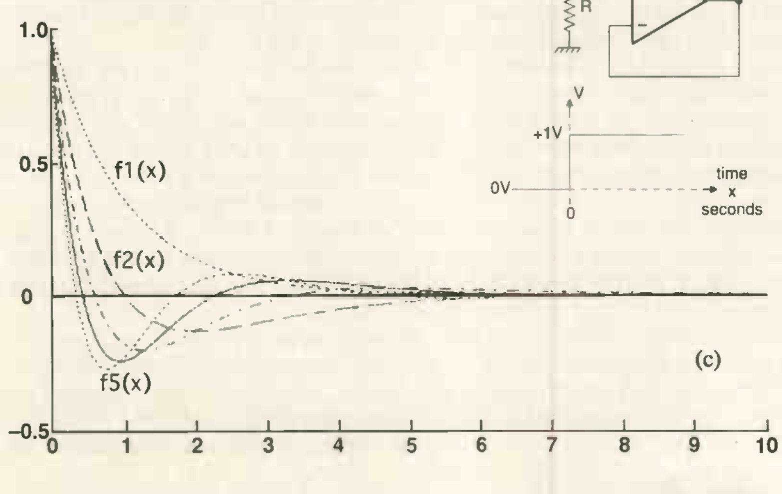
An interesting alternative to the high-pass filter is the synthesis of a high-pass response by subtracting the output of a low-pass filter from the original signal. At very low frequencies where the output of the low-pass filter is identical to its input, the result is no signal, while at very high frequencies where the output of the low-pass filter is zero, the input signal simply constitutes the output signal.

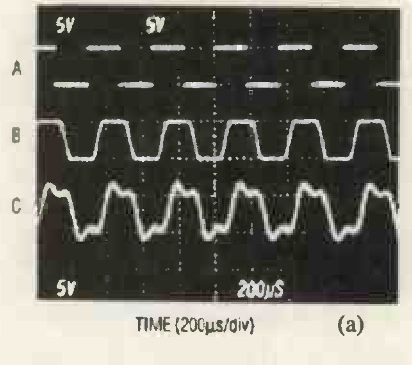
Less than satisfactory is the part in-between, where the output of the low-pass filter is at an intermediate amplitude and phase-shifted to boot, resulting in partial cancellation, and a slow transition from the stop-band to the pass-band. Nevertheless, the arrangement is attractive, as its implementation calls for a low-pass filter rather than a high-pass type, giving one the choice of a much wider range of ready-made integrated filter circuits.

Such a high-pass filter is illustrated in **Fig. 2a,b)**, which also shows its limitations. For an 8-pole Bessel filter, the attenuation at the cut-off frequency has risen to 3dB and the phase shift has reached 180°. Consequently, the fundamental component of the square wave coming through the low-pass path does not cancel out the same component via the flat path;

Fig. 1a). A 3kHz squarewave (A) emerges from a 10kHz bandwidth, 8-pole Bessel low-pass filter (B) with its edges slowed down B, but otherwise unscathed. By comparison, a similar filter with Butterworth characteristic (C) causes marked ringing. This would be even more pronounced with Chebychev or elliptic Cauer filters. At (b), a 5-pole, high-pass filter consisting of five cascaded, first-order stages, with a step-function input. c) shows the response at each of the five outputs, showing that the nth output crosses the zero voltage baseline n–1 *times.*







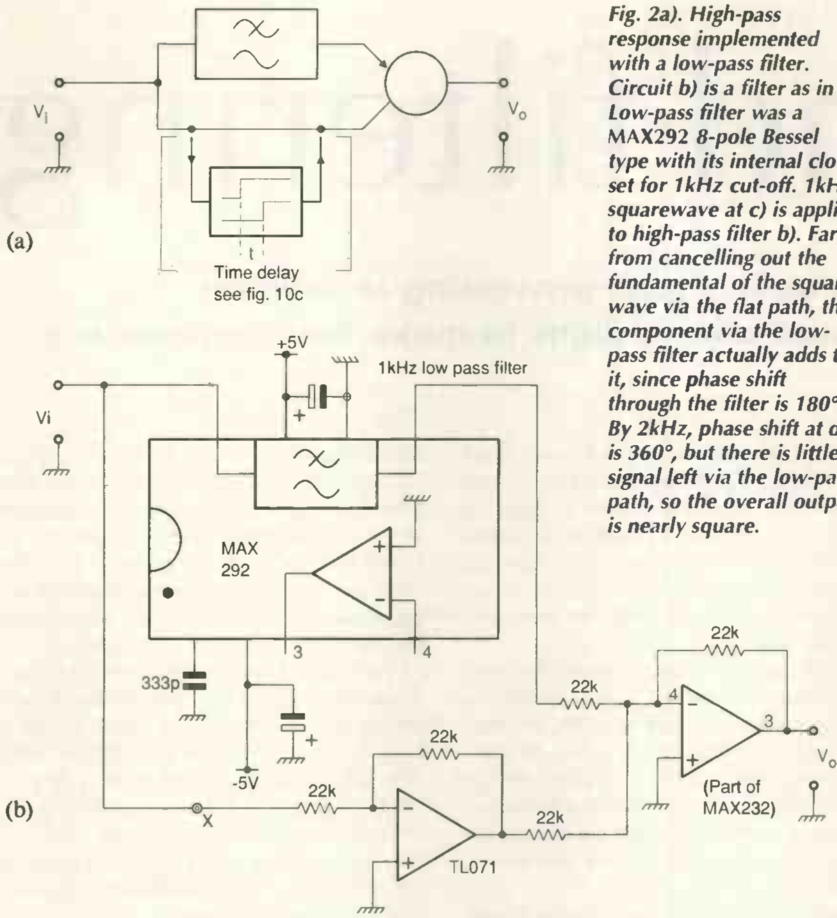
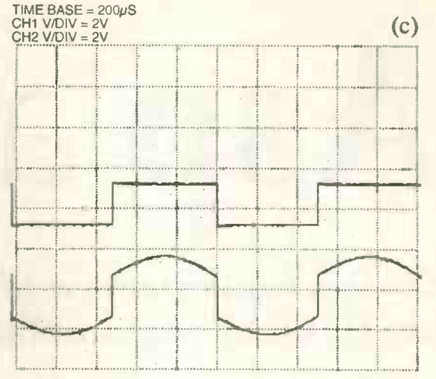
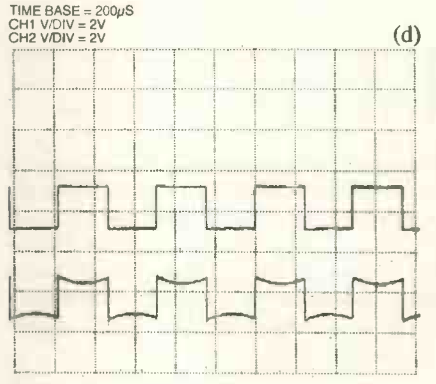


Fig. 2a). High-pass response implemented with a low-pass filter. Circuit b) is a filter as in a). Low-pass filter was a MAX292 8-pole Bessel type with its internal clock set for 1kHz cut-off. 1kHz squarewave at c) is applied to high-pass filter b). Far from cancelling out the fundamental of the square wave via the flat path, the component via the low-pass filter actually adds to it, since phase shift through the filter is 180°. By 2kHz, phase shift at d) is 360°, but there is little signal left via the low-pass path, so the overall output is nearly square.





indeed, due to the 180° phase shift, it adds to it, as in Fig. **2c**).

An eight-pole Bessel filter has constant group delay (phase shift proportional to frequency) well past the cut-off frequency, almost up to twice that frequency – in fact the data sheet for the *MAX292* used in the circuit of Fig. 2b) shows it as completely flat to $2f_c$. Consequently, at that frequency the phase shift through the low-pass path has reached 360° and the signal via the low-pass path is again subtracting from that via the flat path. However, the signal is by now much attenuated so the flat top of the square wave is by now only slightly dented, as in Fig. **2d**), and quite flat at $3f_c$ and upwards.

This simple high-pass filter also has a limited performance at low frequencies. **Figure 3a)** shows a 100Hz square wave applied to the basic low-pass filter, upper trace, and its output, lower trace. Bessel response shows no ringing, but there is clearly a finite time delay through the filter. Subtracting the two waveforms allows the edges of the input through to the output before the low-pass filter output arrives to cancel the rest of each half cycle of the square wave. Fig. **3b)** shows the result.

Figure **3c)** shows the effect of inserting a pure frequency independent time delay, implemented using a bucket-brigade device ,bbd, of which more later, into the flat path at the point labelled X in Fig. 2b). In this case the bbd clock frequency is too low, giving too long a delay, with the result that the Bessel low-pass filter output now leads the broad-band signal via the flat path – compare Figs. 3b,c).

Increasing the bbd clock frequency just sufficiently reduces the delay to site the edge of the delayed square wave in the middle of the rise time of the low-pass filter output, Fig. 3d). Whereas the lower trace in b clearly contains a component at 100Hz, together with harmonics of that frequency, the lower trace in d is virtually devoid of any 100Hz component.

This is confirmed by the spectrum of the lower trace of Fig. 3d), shown in Fig. 3**e**), covering 0-5000Hz. At frequencies above about 2kHz, the harmonics of the square wave roll off at the rate expected and attenuation at 100Hz is well over 40dB.

Comb filters

It may happen that interfering signals lie within the bandwidth occupied by a wanted signal, a typical example being mains hum and its harmonics. All is not lost; it may be possible to remove the interference, whilst keeping most if not all of the signal energy, by using a comb filter – a filter with a series of notches at nf_o, where f_o is the frequency of the lowest notch, and n=1, 2, 3, etc.

A useful device in this context is the bbd, mentioned earlier, which subjects a signal to a time delay, the value of which is determined by the frequency of a clock signal applied to the device. Having experimented with such a device in the past to produce artificial reverberation in connection with an electronic organ, I unearthed the breadboard, the circuit of which is shown in **Fig. 4a)**.

As shown, the circuit ran at the very low clock frequency of about 8kHz, limiting the useful bandwidth to about 2kHz. Maximum delay provided at the output tap (stage 3328) was about 200ms, and the circuit had provision for adding in contributions from any or all of the intermediate taps, at various strengths, by means of the six-way dil switch SW_B. Delays at the intermediate taps, stage 386, stage 662, etc, as a fraction of the maximum delay, are all chosen to be irrational numbers to simulate the various reflection delays and resulting eigentones in a large building.

To extend the maximum delay to one or more seconds, I used a similar arrangement of select-on-test resistors and dil switch in the path via $IC_{1d,c,b}$. Output v_{o1} consists of the input signal plus selected, delayed versions summed at the virtual earth input of IC_{1d} and added to the direct signal. For the purposes of simulated reverberation, I found it best to recirculate solely via the maximum delay, tap 3328, adding different delays only at SW_B, the input of the output path to v_{o2} via IC_{1a}, IC_{2b}.

I used the *MN3011* bbd chip, RS No. 631-294, which is a pmos device and is thus rated to operate between a V_{ss} of 0V and a V_{dd} of −15V, although for convenience it is usual to operate it from a positive supply, as shown in Fig. 4a. It needs a two-phase clock, which was provided by the *CD4011*, IC_4. Any overlap should be limited to within 3V of the positive rail, a condition which the circuit shown very nearly met.

Op-amp inputs are referred to a nominal midpoint voltage adjusted by the 220kΩ pot., which was set for minimum distortion on maximum amplitude signals. The 100kΩ pot. at the output of IC_{1d} permits adjustment of the degree of recirculation, and hence of the length of reverberation.

Naturally, if advanced too far, the loop gain exceeds unity and the circuit oscillates.

Comb notch filter

I modified the bbd circuit to run as a comb notch filter, by combining the signal with a delayed and inverted version of itself, but without any recirculation of the signal via IC_{1d} and using the first tap, stage 396 output, to give a delay of 25ms. Thus a sine wave at 40Hz would be delayed by exactly one cycle, and when inverted and added to the original signal, should cancel it completely.

The same should apply at 80Hz, 120Hz, etc, whilst at 20Hz, 60Hz, 100Hz, where the delay is 180 degrees, the inverted delayed signal will add to the original and give a 6dB increase in amplitude.

This is illustrated in Fig. **4b**), where the broad pass-bands are generally 20dB above the narrow stop-bands or notches; greater notch depth can be achieved by careful adjustment of the gains in the direct and the delayed inverted channels. Reduced amplitude of the lowest-frequency pass-band, centred on 20Hz, is due to the 100nF coupling capacitor at the input.

A filter with a series of narrow notches can be used to remove mains hum and its harmonics from a signal, while leaving much of the wanted signal energy. If the wanted signal happened to be at 20Hz and/or any of its odd harmonics, it would be passed by the filter in its entirety, completely unscathed.

This arrangement, with a comb spacing of 10.125kHz and known as the 'tête bêche' (head to toe) system, was used years ago to distribute two black-and-white television pictures over cable in urban areas; the two programmes occupied the same bandwidth, but one with its carrier at the bottom of the band and the other at the top.

Carrier frequencies were set so that the line frequencies interleaved, there being negligible energy except in the immediate vicinity of each line frequency harmonic in normal picture content. Appropriate filters separated the one signal from the other, there being but two programmes to choose from in those days.

Selective comb-pass filter

If the inverted delayed channel signal is removed and a portion of the delayed signal is added back into the original signal, by closing one of the switches in SW_A, what were previously notches now correspond to frequencies where the delayed signal is in phase with the original, giving a series of peaks. Midway between each pair of peaks, the delayed signal is in antiphase with the original, so the output is reduced.

When the degree of recirculation is increased to the point where V_{out}/V_{in} at the peaks almost reaches infinity, the gain via the bbd and IC_{1d} must be very nearly unity, since we can almost do without the input entirely. In this condition, the gain at the intermediate points must be 0.5. This follows necessarily, since V_o equals V_{in} minus the delayed version, and the gain via the delayed path has been set to unity; the only solution to the equation $x=1-x$ is $x=0.5$.

Such a selective comb-pass filter was set up using the circuit of Fig. 4a) by selecting the stage-396 tap output at pin 9 of IC_3 with dil switch SW_A, the resistor from there to IC_{1d} input having been changed to 150kΩ. With the pot. at the output of IC_{1d} advanced until the circuit almost oscillated, the frequency response V_{in} to V_{out} was as in **Fig. 4c**). The uniformity of the peaks, from about 330Hz upwards, is remarkable.

Roll-off below this frequency is due to the effect of the 10nF coupling capacitor at the input of IC_{1d}, which is much more pronounced on the peaks than on the troughs, where the feedback via the delay is negative, nicely illustrating how positive feedback emphasises variations, while negative feedback flattens them out.

I selected the capacitor during the earlier synthetic reverberation experiments, to avoid boominess – a realistic reverberation effect does not require an extended frequency response, in either the treble or the bass.

Where the wanted signal and its harmonics are at a known frequency, you can use a selective comb-pass filter by setting the bbd clock frequency so that the peaks pick out the wanted signal components, substantially reducing the system bandwidth and cutting out much of any broadband noise which may be present. However, carried to extremes, the narrow bandwidth of the peaks means that very rapid changes in the wanted signal cannot be accurately followed.

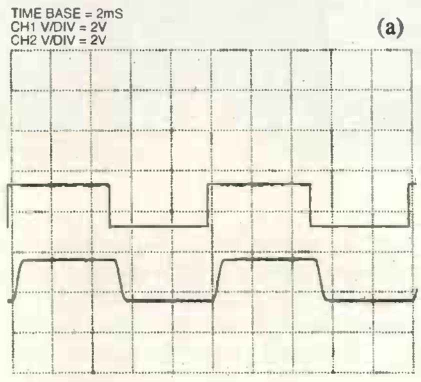
Bbd strips noise

An interesting alternative is to use a selective comb-pass filter not to pick out the wanted signal from the interference, but to pick out the interference from the wanted signal. You then subtract the interference from the original mixture of signal and interference, leaving just the signal. This application is feasible where the interference is an unvarying waveform or, in signal-processing jargon, the interference is a 'stationary' signal.

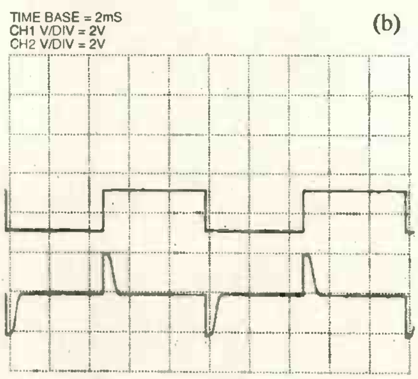
Before trying out this scheme, suggested by

Fig. 3a). A 100Hz squarewave applied to the basic low-pass filter of Fig. 2a), upper trace and its output, lower trace. Bessel response shows no ringing, but there is a finite time delay through the filter. Due to the time delay, the simple high-pass scheme of Fig. 2a&b) lets the edges of the input through before the low-pass filter output arrives b) to cancel the rest of each half cycle of the squarewave. Adding time delay c) in the flat path is in this case excessive, as the low-pass filter output now leads the squarewave coming through the flat path. With just the right delay, d) shows the direct and low-pass signals arrive at the output at the same time. e) Spectrum of the lower trace in d) illustrates that there is hardly any 100Hz component.

(a)



(b)



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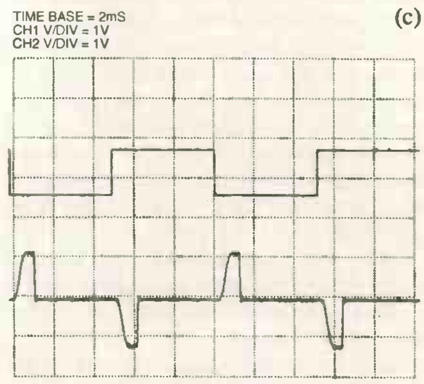

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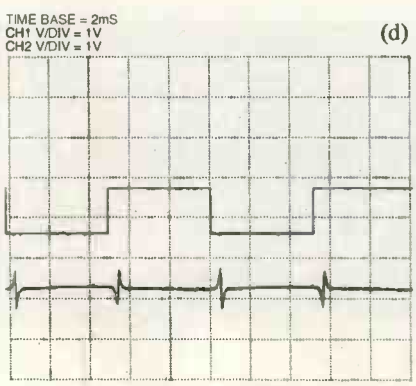

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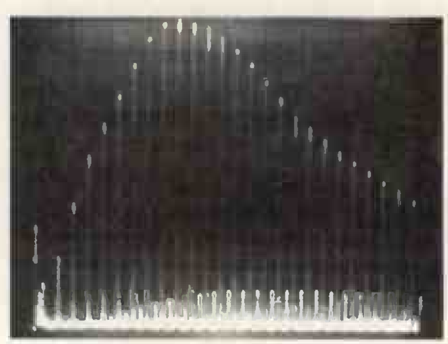


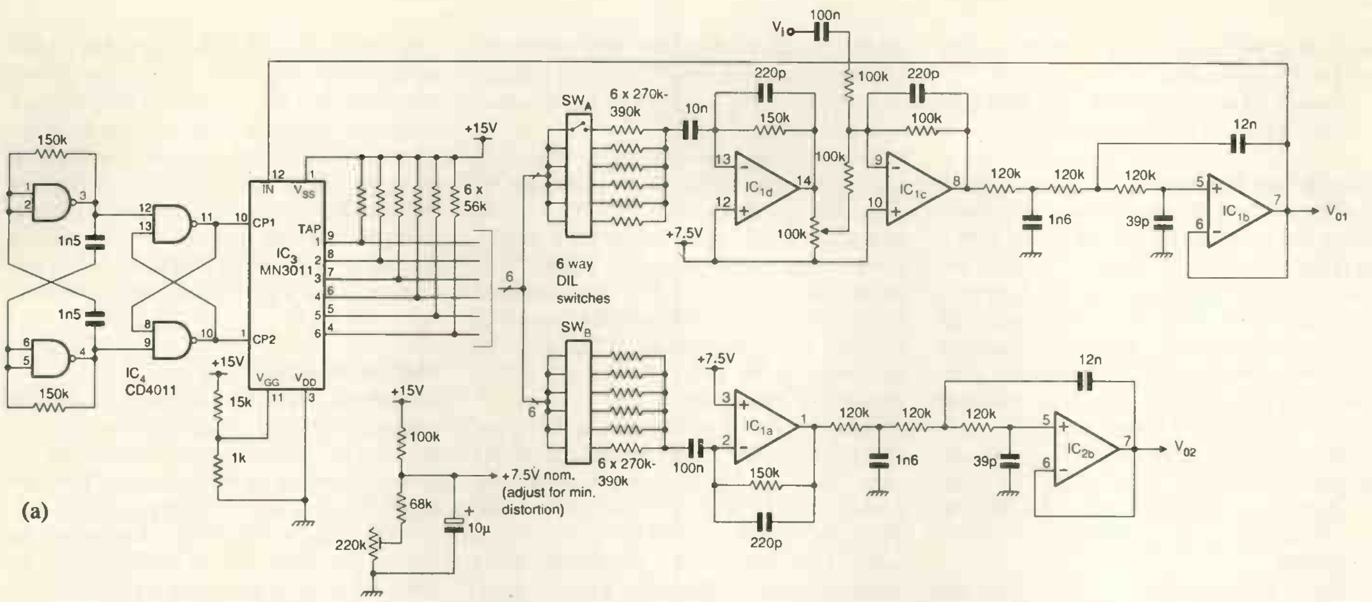
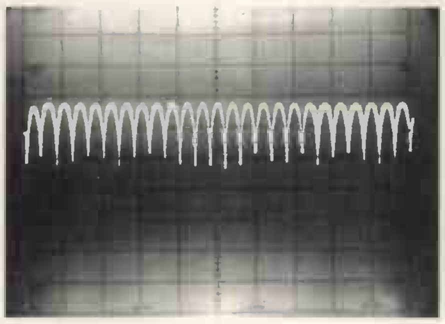
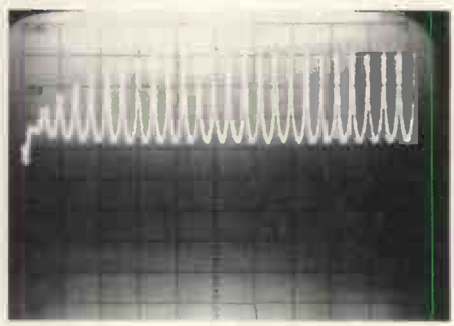


Fig.4a). Circuit of an experimental bbd delay system, originally used for experiments with reverberation. With all sections of SW_A off, and a delayed inverted version of the signal summed with the original input, b), a comb notch filter resulted. Delayed signal was taken from bbd tap 1, stage 386, giving a delay of 25ms. Spectrum analyser display: vertical, 10dB/div.; horizontal, 0-1000Hz span. With the pin 9 output from stage 396 selected via SW_A, as in c), the degree of recirculation was set just short of oscillation, resulting in a selective comb-pass filter. Delay and analyser settings as in b).


(b)


(c)

a colleague at work, I modified the earlier breadboard bbd circuit to incorporate an *MN3101*, the recommended matching clock driver ic, in place of the *CD4011*.

The *MN3101* has several advantages over the earlier arrangement: its two-phase clock outputs meet the bbd chip's requirement that the clock edges should cross within 3V of the positive rail; and it is tuned by just a single *RC* circuit, against the two used by the cmos oscillator in Fig. 4a), a great convenience when fine-tuning a highly selective filter. It also provides the gate bias voltage required by the bbd chip, disposing of the potential divider at pin 11 of the *MN3011* in Fig. 4a).

Tuning with a single resistor was going to be important in this application, where the narrow band-pass comb filter was to be tuned to an interfering signal.

I needed a wanted signal, and some interference. Choosing the interference was simple – the old enemy, mains hum. Often, this is not merely a 50Hz fundamental, which could be rejected by a simple notch filter, but contains both odd and even harmonics. Even harmonics usually emanate from rectifier circuits, while the odd ones come from coupling with the leakage flux of mains transformers.

For reasons of cost, transformers are commonly designed to operate the core up to a peak flux density verging towards saturation, resulting in a component of magnetising current at the third and higher odd harmonics. The fundamental component of the flux stays mainly on the core, but the leakage flux is rich in third and higher odd harmonic components.

I used the circuit of **Fig. 5a)** with the point X open circuit to provide a source of fairly nasty mains hum, with even harmonic components provided by the rectifier circuit, and odd components (including the fundamental) by the 25-turn coupling winding, which was wound around the outside of the transformer, thus coupling only with the leakage flux.

(a)

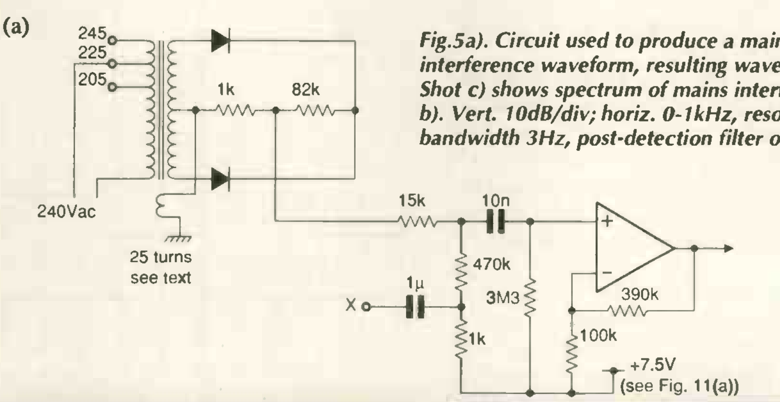
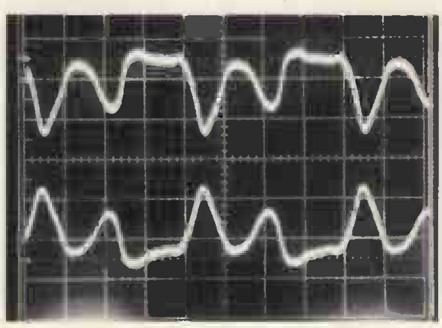


Fig.5a). Circuit used to produce a mains related interference waveform, resulting waveform at b). Shot c) shows spectrum of mains interference in b). Vert. 10dB/div; horiz. 0-1kHz, resolution bandwidth 3Hz, post-detection filter off.


(b)

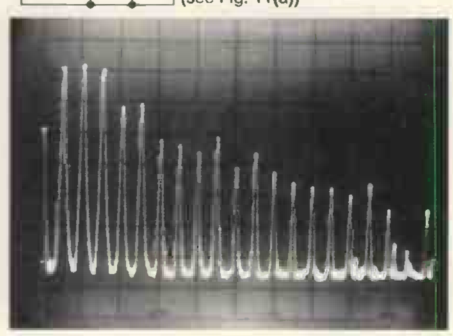

(c)

Figure **5b)** shows the waveform of the resulting hum signal in the upper trace. Counting all the peaks, indicates that it contains components up to at least the fourth harmonic, but its spectrum shown in Fig **12c)** is more revealing. It shows that the fundamental, first and second harmonics are all at the same level within a decibel or so, while even the ninth harmonic is not much over 20dB down on these. Not until the eighteenth are the harmonics more than 40dB down on the fundamental.

Figure 6a) is the modified version of the bbd breadboard circuit of Fig. 4a), now incorporating the *MN3101* clock driver and intended to act as an interference cancelling circuit. Input V_i is the mains interference waveform of Fig. 5b) (upper trace). Gain to this signal, from V_i to V_{o1}, is 0.1 or –20dB, set by the ratio of R_1 and R_2, at IC_{1c}.

However, I set the bbd clock frequency so that the lowest frequency response peak was at 50Hz, and adjusted R_3 at the output of IC_{1d} so that V_{o1} equalled V_i, apart from the inversion in IC_{1c}, as is shown by comparing the lower trace (V_{o1}) in Fig. 5b) with the upper (V_i). Thus the gain around the loop IC_{1c}, IC_{1b}, IC_3, and IC_{1d} was 0.9, and the recirculated signal, added to the smaller input signal via R_1, results in amplitude of V_{o1} being the same as V_i.

If now V_i is disconnected, the amplitude of V_o will fall by 10% for the immediately following 20ms, since the input to IC_{1c} now consists solely of the signal coming from the delay line. For the 20ms after that, it is 90% of 90% or 19% smaller, and so on, gradually dying away to nothing. Likewise, when v_i is reconnected, initially V_{o1} is only 10% of V_i, building up asymptotically to its full value, see Fig. 6b), showing V_i upper trace – V_{o1} lower trace. Over many cycles, the circuit builds up and stores a replica of the mains interference.

Connecting a 4Vpk-pk square wave at approximately 8Hz to point X in Fig. 5a) provided the 'wanted signal', differentiated by the 1ms time constant of the 1μF and 1kΩ *CR* circuit, to give the narrow pips visible in Fig. **6c)**, upper trace. This was the input V_i to the circuit of Fig. 6a), which generated a replica of the mains interference at V_o, as before.

The pips do not feature in this replica as they only appear infrequently in V_i, and not in the same place in the waveform each time. The pip repetition rate is (20×*n*)ms, where *n* is *not* an integer. So, when the recirculating version of the interference is subtracted from V_i, the result at V_{o3} in Fig. 6a) is simply the wanted signal as in Fig. 6c), lower trace.

Recovered signal is not entirely in the clear. Firstly, its amplitude at V_{o3} is only 90% of its input value, due to summing with the inverted, one-tenth-amplitude version of it appearing at V_{o1}. Secondly, this inverted 10% version is applied to the bbd delay input, to reappear after 20ms at V_{o1} as a re-inverted 9% version.

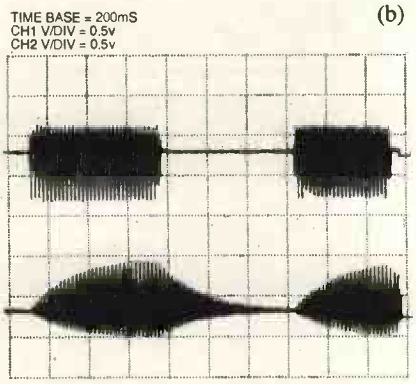
This appears as such at V_{o3}. You might just fancy you can see it as an echo one horizontal division after the pip in the lower trace of Fig. 6c), lurking among the background noise, which is mainly clock hash.

In a practical interference-suppression system using this scheme, the clock for the 3328 stage bbd chip would be maintained at exactly twice 3328 times the mains frequency. This would be carried out by a phase-locked loop, which follows any slight drift in mains frequency. Since this would occur slowly, the interference may still be considered stationary.

This scheme works for isolated signals occurring at random intervals and for repetitive signals such as pulses – short compared with 20ms – provided that they do not recur at intervals or submultiple of 20ms. If they do, they will appear as a stationary signal of the same period as the hum, and will build up a replica in the same way. When this is subtracted from the original nothing will be left. ■

References

1. Lerner, RM. Band-pass filters with linear phase. *Proc. IEEE*, March, 1964, pp. 249 - 268.
2. Delagrange A. Bring Lerner filters up-to-date: Replace passive components with op-amps, *Electronic Design* 4, February 15, 1979, pp. 94-98.



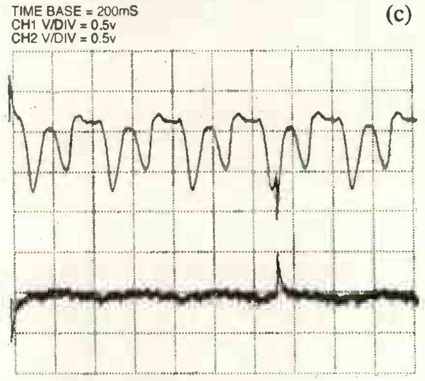
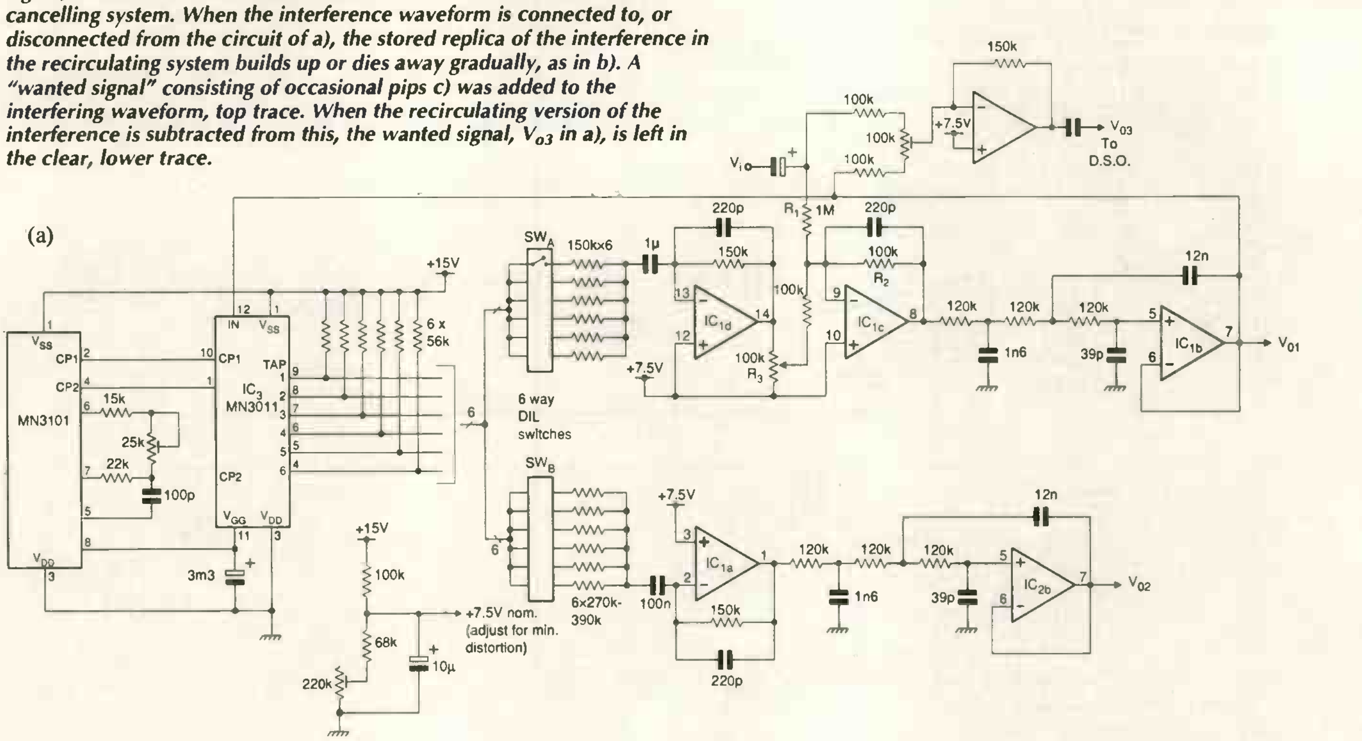


Fig.6a). Bbd device comb filter modified for use as an interference cancelling system. When the interference waveform is connected to, or disconnected from the circuit of a), the stored replica of the interference in the recirculating system builds up or dies away gradually, as in b). A "wanted signal" consisting of occasional pips c) was added to the interfering waveform, top trace. When the recirculating version of the interference is subtracted from this, the wanted signal, V_{o3} in a), is left in the clear, lower trace.



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Hf voltage-controlled oscillator

Three h-cmos inverters in a *74HC04* form a ring oscillator whose frequency varies with a 1.5-5.5V control voltage that alters gate delays, frequency varying as $^{1}/_{6t}$.

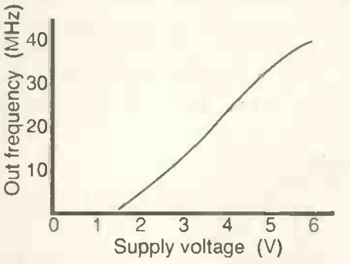
One amplifier and an output buffer used alone – the top half of the circuit – produce a square wave, but the rest of the circuit takes the square wave and turns it into a sinusoidal output.

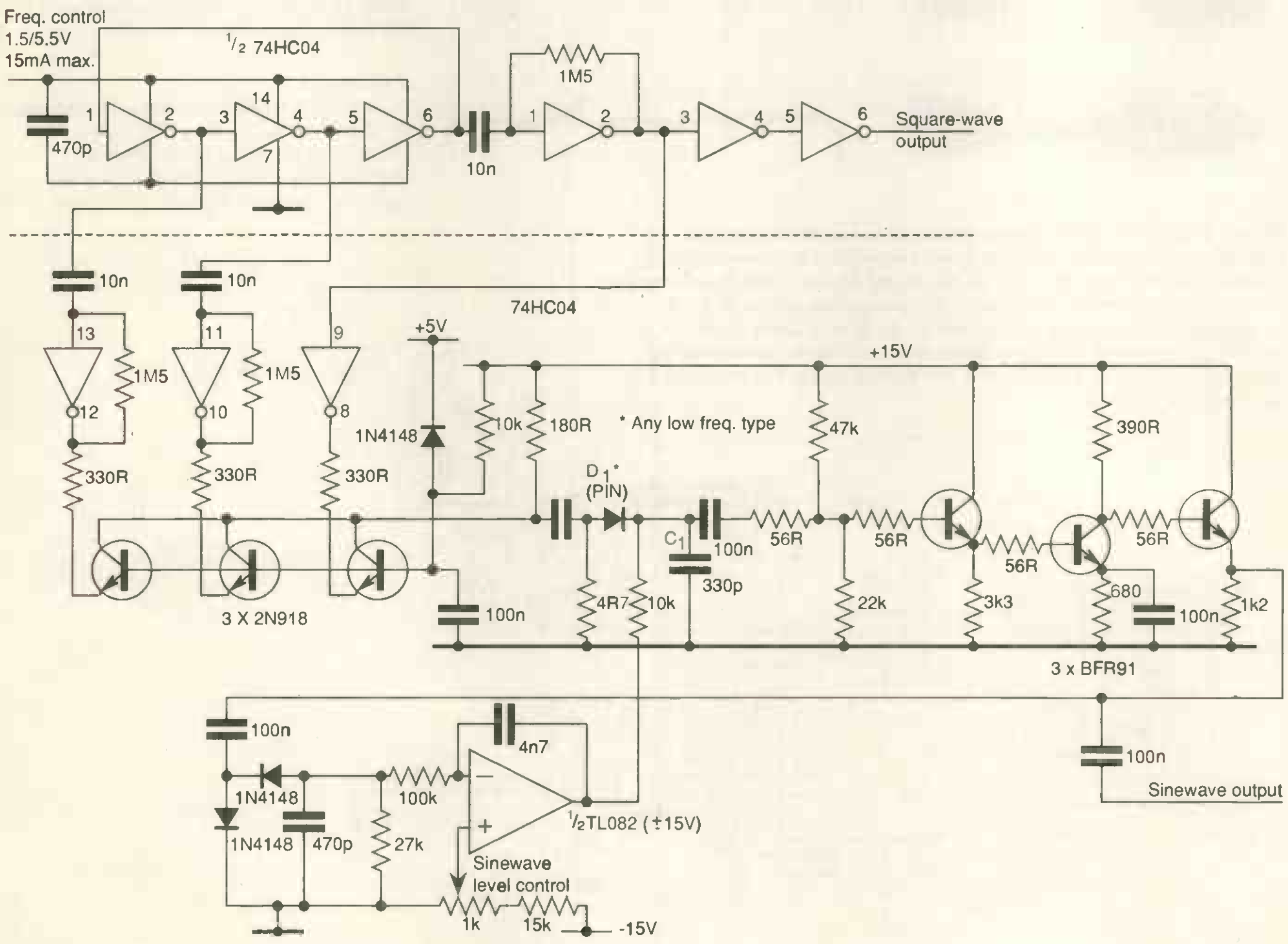
All three phases from the ring oscillator combine in the three further inverters to give a stepped, triangular output, which passes through the variable cut-off, low-pass *RC* filter. Cut-off frequency of the filter automatically tracks the oscillator frequency by means of the feedback loop consisting of a peak detector and amplifier driving the pin diode.

Short-term output frequency variations show a random element and one related to the mains frequency, both 1kHz wide and of about the same amplitude and both worse below 2MHz. Temperature variation is around 0.5%/°C at 10MHz for the free-running oscillator – a small problem in the intended synthesiser application.

Giuseppe Faini
Milan
Italy

This variable-frequency oscillator spans 2-40MHz for a direct control voltage input of 1.5V to 5.5V, producing both sine and square outputs.





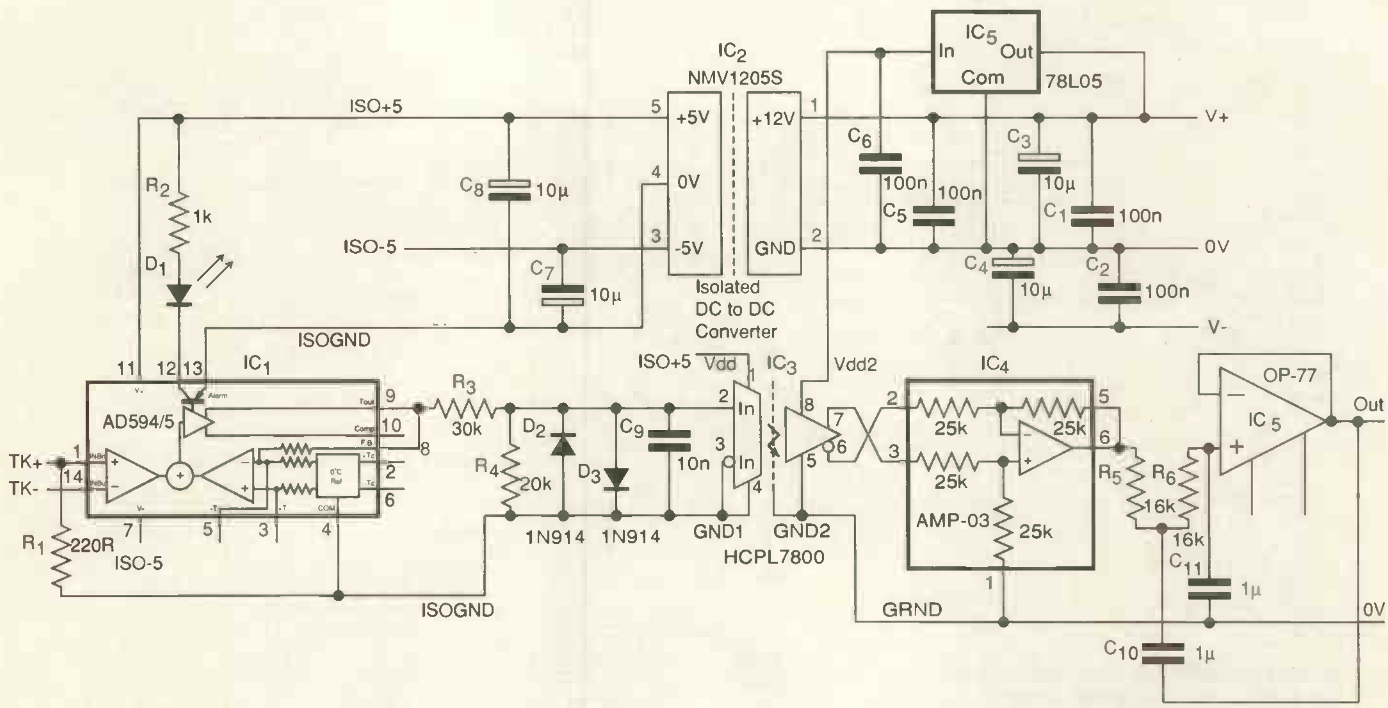
Thermometer amplifier provides isolation

At the core of the circuit is an *HCPL7800* optical isolation amplifier, taking its input from an *AD594* or *AD595* thermocouple amplifier for J and K sensors respectively, which also drives an open-circuit indicator led. Potential divider $R_{3,4}$ must be calculated to present less than ±200mV to the isolator, the values shown giving an output of 32mV/°C.

An *AMP 03* differential amplifier provides a single-ended output to a low-pass filter cutting off at 10Hz or whatever frequency is needed for the application.

If the *HCPL7800* is hard to obtain, the Burr-Brown *ISO130P* is a pin-compatible alternative and the AMP 03 can also be replaced by the *INA105KP*.

Alex Birkett
London SE 22



Complete circuit of a 32mV/°C isolated thermometer, which covers 0-50°C or a range set by the values of two resistors.

£100 WINNER

Remote multichannel resistance measurement

This low-power circuit measures the value of remote resistive sensors using any type of connection such as wire, infrared or ultrasonics; I use a vhf radio link. With a *UMC UM3758-108AM* encoder/decoder, it is possible to transmit 8-bit data combined with 10 address bits. Depending upon the logical level on the mode input, the circuit acts as a decoder or encoder. In this application, the address bits are hard-wired high and the measuring resolution is limited to 6-bit, for reasons explained later.

In encoder mode, the Tx/Rx pin transmits the address/data information as long as power is supplied. A built-in *RC* oscillator, with only two external components (R_9, C_9) is used as a clock; matching of the encoder/decoder's oscillator frequencies is not very critical and 5% resistors are sufficient.

Serial data is supplied to the Rx input in decoder mode, where it is examined bit by bit as received. Only if two successive address/data combinations match is data transferred to the output data pins $D_{1\text{-}8}$, which latch the data until the next valid data is being received. The Tx/Rx out pin switches low if data matches, returning high after two successive unmatched address words.

System timing is controlled by IC_1, a *74HC4060*. The positive-going edge of the *Q5* output of IC_1 triggers an enable signal, the duration of which is adjustable by P_1 about every 60s, depending upon R_1, R_2, C_1. At the start of this enable time, the counter in IC_4 is reset to 0 by the positive-going edge of the oscillator enable signal via C_3, R_4. Diode D_8 gates the IC_4 clock signal, pulling down the clock input to disable counting. During the enable time, a sensor-dependent count is reached on the outputs $Q_{4\text{-}9}$. Be careful to avoid overflow, by selecting the right combination between the enable time and the IC_4 oscillator frequency, which depends on the sensor used.

At the end of the oscillator enable time, the down-going edge of IC_{5b} Q output triggers IC_{5a} to switch on the power supply for both the *UM3758* and the transmitter. To be sure that a minimum of three address/data codes are transmitted, the transmitter on time, adjustable by P_2, is 250-300ms. Raising the *UM3758* oscillator frequency makes it possible to use an even shorter transmitter time, but bear in mind that the receiver must be capable of detecting this signal. A low-loss, dual P-channel mosfet, a Siliconix *SI9933DY* with $R_{gs}<0.2\Omega$, switches the transmitter/encoder supply.

To prevent any current flow through the data input of IC_2 when it is powered down, the counter outputs of IC_4 are connected via diodes $D_{1\text{-}6}$. Because of the internal architecture of the *UM3758*, an open input will be seen as logical 1, so there is no need to use pull-up resistors.

Logic levels of data bits D7 and D8 are user selectable to allow the use of four transmitters on the same frequency without changing decoder address lines in the receiver. A small difference in transmitting interval will prevent most of the interference when more than one transmitter is used.

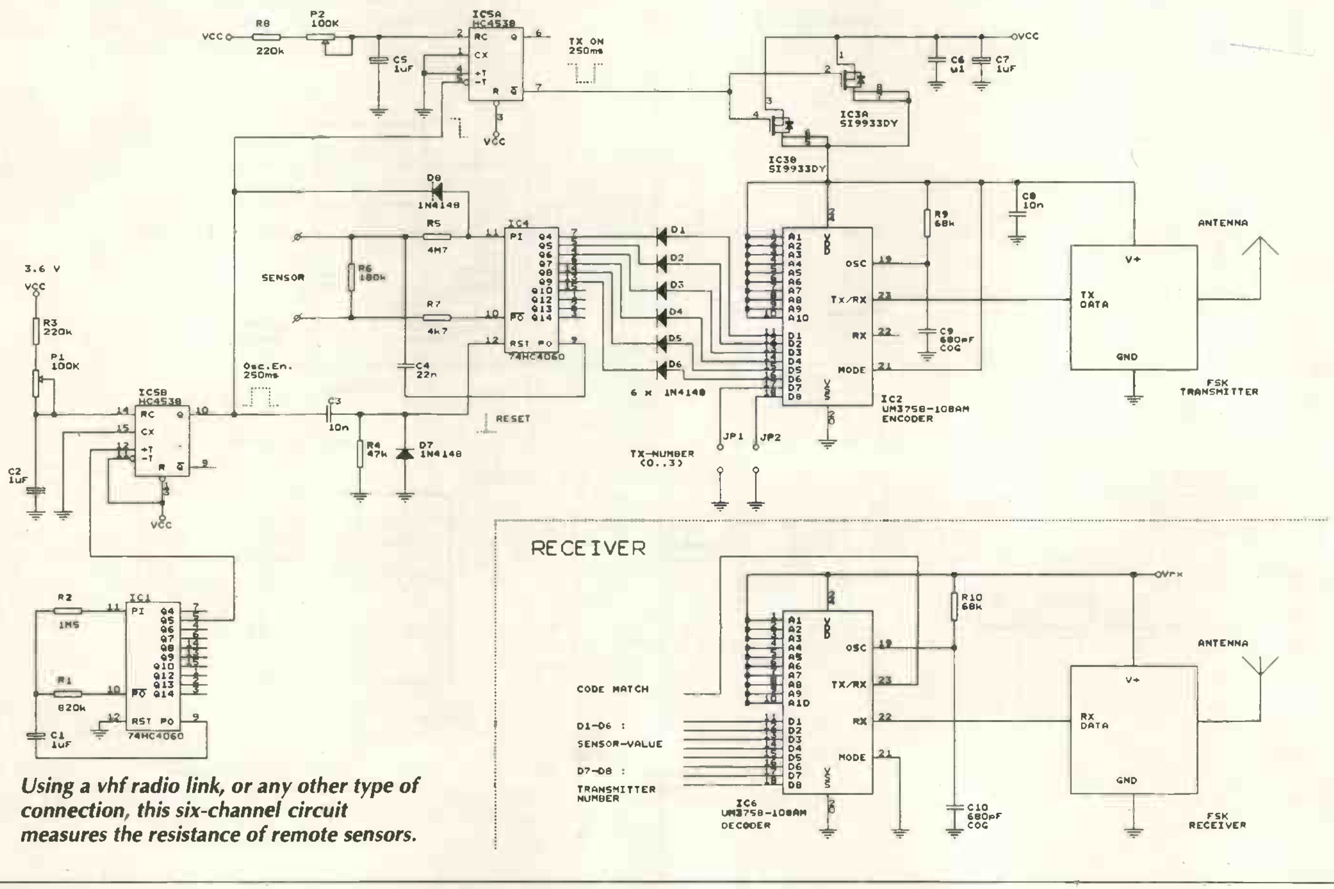
Powered by a 3.6V lithium cell, the transmitter logic draws less than 100μA, transmitting current depending upon the type of transmitter used, although overall power consumption is still low because of the short transmitting time. A telemetry system based on this design has been in use by our institute since early 1994 to study activity and feeding behaviour of the red deer. As the resistive element we use an electrolytic tilt sensor. I built the circuit using surface-mounted components but, except for the *SI9933DY*, they are also available in through-hole form.

Willem van der Veer
Institute for Forestry and Nature Research
Wageningen
The Netherlands.

References

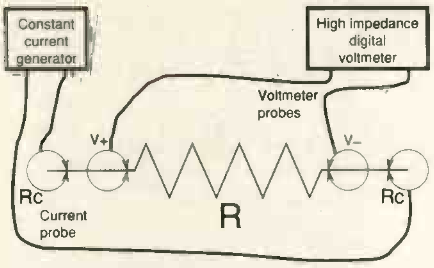
UM3758 series data sheet, UMC Europe, Amsterdam, The Netherlands. Telephone: 0031-20-6970766.

Little Foot series manual, Siliconix Ltd, Newbury, Berks RG14 5UX. Tel. 01344-485757.



Using a vhf radio link, or any other type of connection, this six-channel circuit measures the resistance of remote sensors.

Dvm to milliohm meter

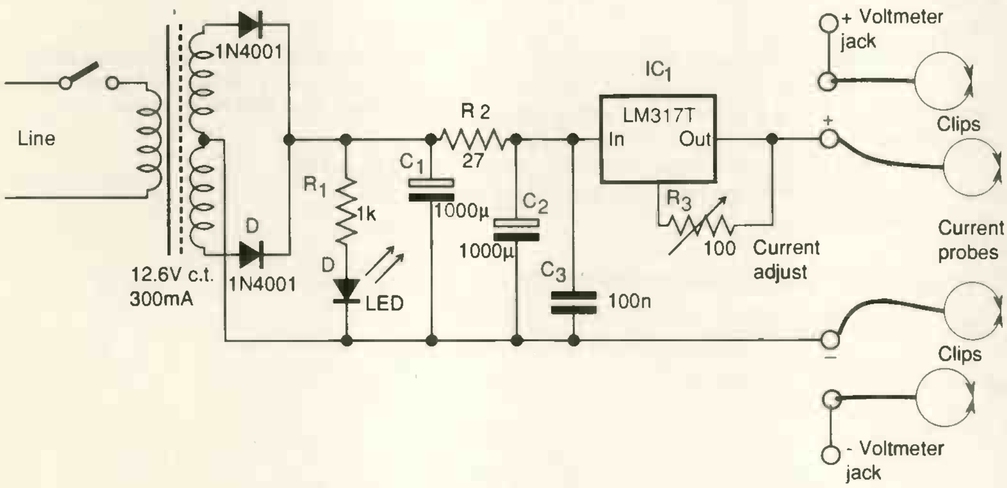


Digital voltmeter adaptor enables it to measure down to 1mΩ by forcing a constant current through the circuit and separating the voltage measurement.

High and variable probe contact resistance set a lower limit to the resistance measurement facility when a digital meter is used in the normal way to supply a current and to measure the consequent voltage drop across the resistor. Resolution is also commonly 100mΩ which is, again, limiting.

The diagram, top left, shows an alternative method in which contact resistance plays no part. A constant, higher than normal, current is supplied separately and the voltage read by the dvm, whose probes must be directly across the resistance to be measured. Input current of a high input-impedance dvm is negligible compared to the 100mA in the measuring circuit. Resistance is the voltage reading multiplied by 10, i.e. 100mV=1Ω.

In the practical circuit below, the voltage regulator *LM317T* functions as a constant-current generator, output being set by R_3; a good milliammeter or a precision resistor carrying the current will be needed to adjust the current. Filter R_2C_2 reduces error in the dc-reading millivoltmeter, or a 9V battery may be used.



One shorted turn in a transformer showed up as a reading of 3973mΩ against the 4035mΩ of a functioning unit and it was salutary to see that the resistance of a spliced solid wire was 30mΩ, while when soldered its resistance was 1mΩ. Leads can be of any length, so long as the whole loop does not exceed 10Ω.

Douglas A Kohl
Osseo
Minnesota, USA

Median filter for spike reduction

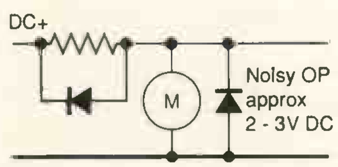
This type of filter finds the median level of an analogue signal, that being the level that is exceeded 50% of the time. Filters of this type reduce spikes while maintaining edges of a waveform.

An *LM339* comparator changes state when the input crosses the median level, forcing the *LM324* integrator to ramp the fed-back median level in a positive or negative direction at around 12000V/s. Transients are therefore limited to this speed.

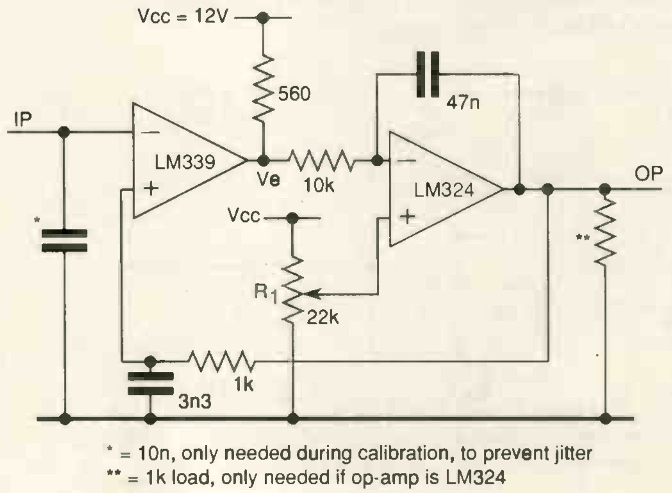
Set the probability level by applying a dc level of say $V_{cc}/2$ at the input, and adjusting the pot until the square wave V_e has a unity m:s ratio – setting V_e to a 3:1 ratio makes the filter determine the upper quartile of the input, etc.

At the output, a continuous 60kHz, 0.1Vpk-pk triangle wave appears, determined by the *RC* feedback filter; a faster comparator and op-amp would determine the triangle wave by hysteresis, rather than by the filter. Filter the triangle out or leave it as dither for succeeding stages.

W Gray
Farnborough
Hampshire.

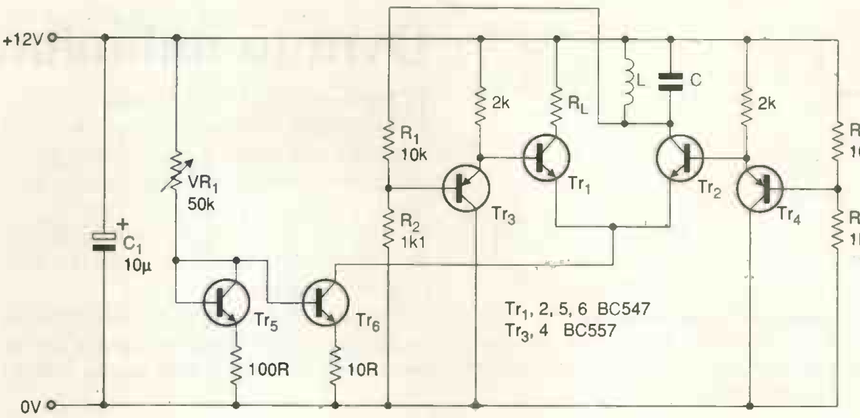


Median filter removes overshoot spikes to leave fast edges. Test circuit, left, demonstrates filter by producing spiky signals.



* = 10n, only needed during calibration, to prevent jitter
** = 1k load, only needed if op-amp is LM324

Q-meter oscillator



Simple oscillator, which nevertheless offers variable output to 20Vpk-pk, at under 1% distortion, from 100kHz to 2MHz.

Although simple in design, this 100kHz-2MHz oscillator provides a variable-amplitude output at low distortion and is suitable for use as the oscillator in a *Q*-meter, other types of instrument or in communications.

Tail current in the differential pair switches between collector loads on alternate half cycles, the load to Tr_2 consisting of the *LC* tank circuit. Voltage across the tank is fed back by way of $R_{1,2}$ to the buffer Tr_3 to complete the feedback loop. Symmetry is maintained by Tr_4 and its components.

Current mirror $Tr_{5,6}$ drives the tail current, which is made variable by VR_1 to vary output amplitude and which can be monitored by the voltage on Tr_6 emitter or the switching waveform on Tr_1 collector. The tank circuit provides a filtering action on the square current waveform to give less than 1% distortion even at low *Q* values. Square waves at Tr_1 collector may be useful as synchronisation to other circuits.

On a 12V supply, output swing before clipping is 20Vpk-pk, approximately symmetrical about the positive supply rail. If the oscillator is to be used in a measuring instrument, loading of the feedback circuit should be considered. An unknown *L* can be calculated from the frequency and known resonating capacitance.

$$R_d = V_{pk\text{-}pk}/1.27I_{pk\text{-}pk} \text{ (dynamic resistance)}$$

$$Q = R_d/(6.28f_oL),$$

where $L = 1/C(6.28f_o)^2$

M J Hutchings
Salisbury
Wiltshire

Level-shifter generates square waves

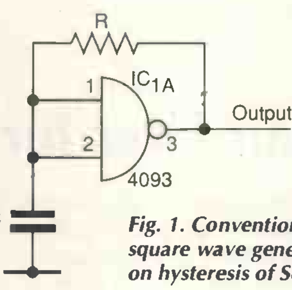


Fig. 1. Conventional single gate square wave generator relies on hysteresis of Schmitt. nands

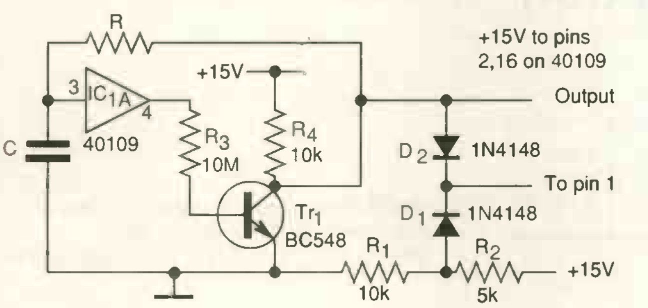


Fig. 2.Single gate generator offers a wide range of frequency and mark:space ratios.

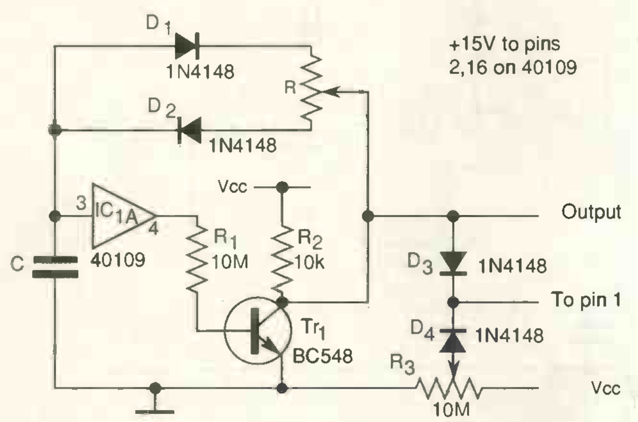


Fig. 3.Enhancement of square wave generator Fig. 2 includes adjustments for frequency and mark:space ratio.

Single-gate square-wave generators often use the hysteresis of Schmitt nands, **Fig. 1** to change state. This one uses a *40109* level shifter that offers access to both V_{cc} and V_{dd} on separate pins.

In **Fig. 2**, initially, *C* is discharged, the output of the 40109 is low, the transistor is off and circuit output is at around 15V. Point B is 10V and, since D_1 is reverse-biased and D_2 forward-biased, V_{cc} to the ic (pin 1) is at about 15V. The capacitor starts to charge through *R* and when it reaches 7.5V the output of the ic goes high, the transistor conducts and the output goes low.

Diode D_1 is now forward-biased, D_2 reverse-biased and V_{cc} about 10V, after which the cycle repeats. Mark:space ratio is 1:1, since the capacitor charges and discharges through the same resistor.

Figure 3 shows a developed circuit with adjustments for frequency and mark:space ratio.

V B Oleinik
Kaliningrad
Moscow Region
Russia

Am detector with gain

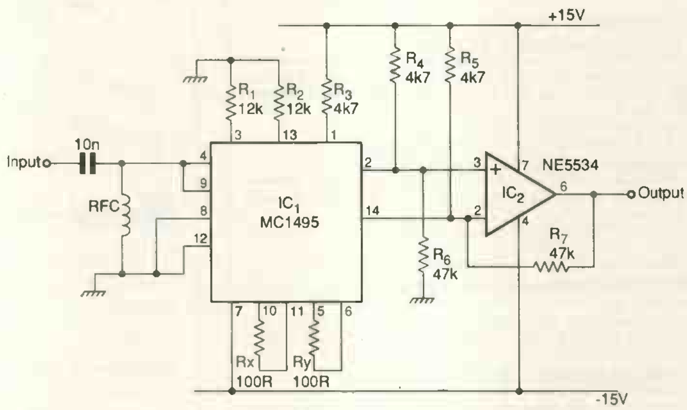
Since the square of a number, positive or negative, is always positive, a squaring circuit inverts the negative half cycle of a signal and forms a detector for am.

This squarer is an analogue multiplier with both inputs connected together so that the output is proportional to the square of the instantaneous input, the multiplier operating in a continuous mode, unlike the switching mechanism of a diode. Op-amp IC_2 converts the balanced output of the multiplier to an unbalanced output at low impedance.

Gain is set by the values of $R_{x,y}$, the smaller the values, the greater the gain. With the values shown, voltage gain is 40 and bandwidth 100MHz. At 30% modulation depth, second-harmonic content of the output is 7.5%.

Peter Goodson
Bracknell
Berkshire

Analogue multiplier with common inputs acts as am demodulator, with a gain of 40.



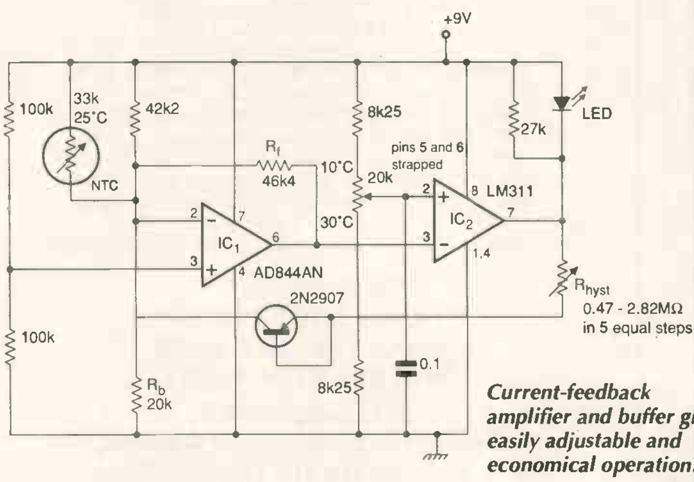
Two-wire connection for both power and signal

A current-feedback amplifier in this thermistor circuit allows the use of a single-ended supply for both voltage offset and bias.

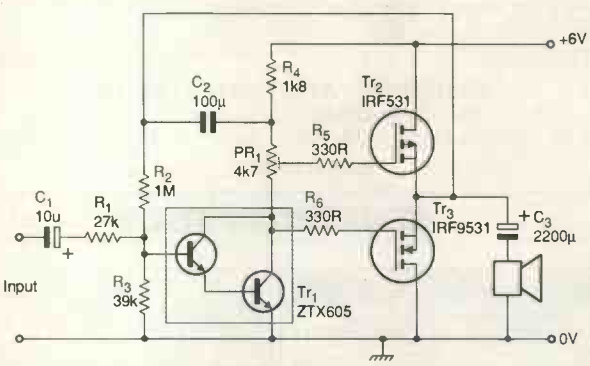
Current to the amplifier inverting input maintains a constant sum determined by the voltage at pin 3 and the current in R_b. Gain resistor R_f therefore sees the output voltage change inversely with thermistor current, the op-amp voltage comparator switching state as its input exceeds the voltage on its pin 2. Hysteresis current through R_{hyst} goes to the summing node via the *2N2907*, used as a diode, since hysteresis feedback current is only 1.5µA/°C; a led indicates the state of the comparator. The 42.2kΩ resistor linearises the thermistor between 10°C and 30°C. Output of the current-feedback amplifier is 2-7Vdc.

Used as a remote monitor, the circuit was supplied by an *ICL7663SCPA* low dropout regulator, which supplied 18mA with the led on and 9mA with it off, so that sensing this step gave a system taking power and sending signal over the same two wires.

John A Haase
Colorado State University
USA



Current-feedback amplifier and buffer give easily adjustable and economical operation.



Very simple 30W audio power amplifier offers a 50kHz bandwidth and 0.1% total harmonic distortion at 30W. Unusually, the circuit operates with a single supply rail.

Simple 30W power amplifier

Using a shunt driver stage eliminates much of the complexity normally associated with audio power amplifiers, while retaining a reasonable performance in terms of its –3dB bandwidth at 10Hz-52kHz and thd of under 0.1% at 30W and 1kHz.

As driver, a Zetex *605* is convenient, but discrete transistors can, of course, be used. Bootstrapping from the output to the junction of the collector-load components by way of C_2 increases the output swing and reduces the effect of mains ripple.

Overall direct feedback is applied via R_2 and R_3 can be selected to cope with different supply voltages, its value being determined by $1.2\times10^6/2V+$. For a change in closed-loop voltage gain, vary R_1. Gain is set by R_2/R_1. ■

J Macaulay
Chichester,
Sussex.

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Multi-channel d-to-as. Dual and single channel, 8-bit digital-to-analogue converters newly introduced by SPT offer high speed and low power consumption. *SPT5100* processes 20Mword/s while dissipating 70mW and the *SPT5110* 30Mword/s at 135mW. Both are intended for use in colour graphics applications. Signal Processing Technologies Inc. Tel., 01932 254904; fax, 01932 254903.

Triple 8-bit d-to-a. Meant for use in video and graphics, Raytheon's *TMC3503* restructures analogue rgb video from the digital form and drives graphics monitors directly. It has single-ended current outputs, takes in SYNC\ and BLANK\ inputs and has a separate current source to add separate sync. pulses to the green d-to-a converter output. Three speed grades give 30, 50 and 80Mpixels/s. An input takes all three converters to maximum value to give reference white for calibration or display. METL. Tel., 01844 278781; fax, 01844 278746.

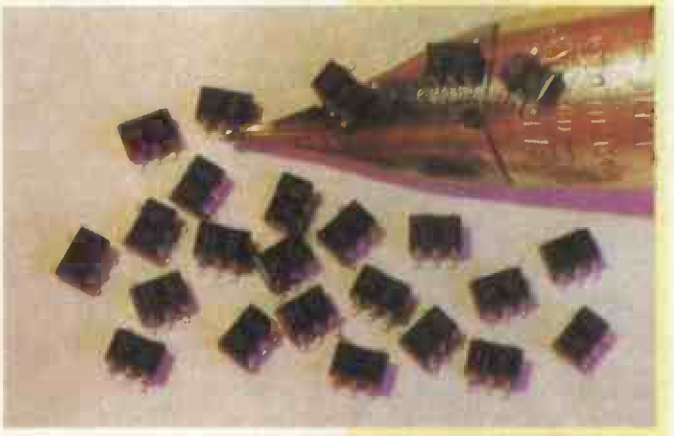
Multiplexer links 8×2Mbit/s data nets. Made by Mitel, the *MT90710* high-speed isosynchronous multiplexer provides point-to-point data transfer between up to eight S-bus links. These links are multiplexed onto a single 20Mbit/s line. The device connects with standard fibre-optic interfaces to form a complete photo-electric conversion circuit. Mitel Semiconductor, Tel., 01291 430000, fax, 01291 436389.

Video d-to-as. Digital-to-analogue converters in the Signal Processing Technology *SPT1018/1019/5140* family offer conversion rates of 165/275/400 million words/s and 8-bit resolution. For video, features include sync., blank, reference white and bright inputs and analogue video output to drive doubly terminated 50Ω or 75Ω loads to standard RS-343-A and RS-170 video levels. There is a feed-through pin to allow registered or unregistered operation between video control inputs and data; in registered mode, composite functions are latched to the pixel data to prevent screen-edge distortion. Ambar Cascom Ltd. Tel., 0296 434141; fax, 01296 29670.

Digital signal processors

Two from Motorola. New from Motorola, the *DSP56005*, a 24-bit digital signal processor with 4608-word program memory and five pulse-width modulators. These features, together with its thin quad flat pack, points the device at industrial control and magneto-optical disk drives and allows the single chip to replace two in many applications such as motor control. A peripheral-select pin eliminates external decoding logic. Also announced is a speeded-up version of the *DSP56002* 24-bit dsp, now running at 80MHz and 40Mips. Motorola Semiconductors. Tel., 01355 565000; fax, 01355 234582.

DSP boards. Bores offers a range of three digital signal-processing boards that use TI's *TMS320Cxx* dsp processors: *Model 250* has the *'C25*; the *Model 310* the floating-point *'C31*; and the *Model 5000* with the *'C51*. Each board contains the processor, analogue i/o subsystem with up to eight channels and a set of software development tools including dsp assembler, debugger and pc interface function library. Application software supplied includes data acquisition and display, FFT analysis and filtering. Bores Signal Processing. Tel., 01483 740138; fax, 01483 740136.



Embedded processor

TI's *TMS320C57S* digital signal processor is a lower-cost version of the earlier *'LC57* and is intended for embedding into mobile radio, navigation comms equipment and similar applications. Its 40mips operating speed is combined with 7Kword of ram, a zero-overhead buffered serial port and a 'glueless' host-port interface to enable the device to handle the large amounts of data i/o for communications without overlnvolving the dsp processor; it eliminates the need for the dsp cpu to service real-time data-frame interrupts from system i/o peripherals such as codecs or a-to-d converters. The device accepts both 5V and 3.3V supplies. SR Communications (Texas Instruments). Tel., 0181 692 7575; fax, 0181 692 8057.

Linear integrated circuits

DSL driver/receiver. *SLIDE* by Elantec is an analogue IC meant for digital subscriber line application. It is a complete differential driver and receiver containing two twisted-pair telephone line drivers and two receiver amplifiers, and will drive differential 45V pk-pk signals at 2MHz into a 200Ω load. Output distortion is –60dB at full 2MHz output and a typical receiver distortion is –73dB at 15Vpk-pk. Supply is ±5V to ±15V. METL. Tel., 01844 278781; fax, 01844 278746.

2.5GHz buffer amplifier. *RF2301* is a wide-band GaAs mesfet buffer for use at frequencies in the 300MHz-2.5GHz range and beyond. Reverse isolation is –50dB and output power 5dBm, so that the device is useful in buffering signal sources to impedance changes or as a transmitter driver. A single 2.7-6V supply is needed and current consumption is 18mA for 17dB total gain. Anglia Microwaves Ltd. Tel., 01277 630000; fax, 01277 631111.

Single-gate cmos. Toshiba extends its series of very high-speed, low-noise cmos with the *TC7SH Logic MOS* single-gate series, comprising Nand, Nor and inverters; the USV package measures 2-by-2.1mm, 0.9mm thick. Propagation delay is 3ns and noise is the same as in slower members of the family. Input protection allows the use of 5V and 3.3V supplies without the need for voltage matching. Toshiba Electronics Europe Ltd. Tel., 001 49 211 52 96-392; fax, 001 49 211 52 96-400.

Logic

3V logic for hand-helds. Hitachi's new high-speed 3V logic elements in the *HD74LV* range are all designed for use on 2.7-3.6V supplies and use only 20μA quiescent current. They complement devices in the *HD74LVC* series and can often be used with them. Zener diodes at the inputs offer protection against es discharge. Propagation delays vary in the 14-30ns range, input capacitance being under 7pF. Eiger Technologies Ltd. Tel., 01925 626626; fax, 01925 626600.

Memory chips

Dual fifos. For cost and space reduction of around 50%, IDT's 18-bit *Dual Sync fifos* contain two independent devices in one package. Although independent, the fifos may be used together with no glue logic, in parallel for extra width or cascaded for more depth; packages can also be

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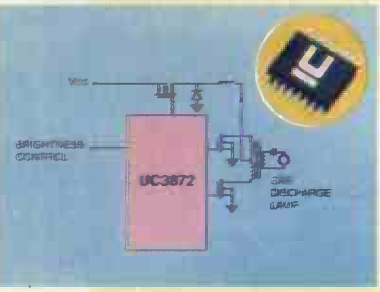

Lamp ballast controller. Optimised for driving cold-cathode fluorescent, neon and other gas-discharge lamps, Unitrode's *UCx872* series lamp-ballast ICs are resonant switching types. Since the resonant converter produces a sinusoidal lamp-drive output, switching losses and emi are minimised. Lamp intensity is adjusted via a buck regulator, synchronised to the external power stage's resonant frequency. When disabled, the device draws 1µA, making it suitable for battery-power applications. Supply for the dil, soic or plcc versions is 4.5 to 24V. Unitrode, Tel., 0181 318 1431; fax, 0181 318 2549.

used in parallel or serially. Ability to store and retrieve data from two sources simultaneously makes the devices ideal for matching data rates in a multiprocessor system. Integrated Device Technology. Tel., 01372 363734; fax, 01372 378851.

Tough memory card. Raymond Engineering's *Sentinel* memory card is ATA PCMCIA-compatible and comes in capacities from 5Mbyte to 40Mbyte. It is hermetically sealed in a stainless-steel case and is thereby resistant to 1500g shock, 20g vibration, altitudes up to 80,000ft, humidity, immersion, condensation, temperature and emi. While the cards can be inserted into an ordinary PCMCIA slot, there is a Sentinel interface unit with a sealed access door and standard bus to provide extra security. Controller and all software is contained in the card. Ambar Components Ltd. Tel., 01844 261144; fax, 01844 261789.

Microprocessors and controllers

32-bit microcontrollers. GPS announces its range of 32-bit embedded controllers, for which it sees an immediate application in the communications field. *Butterfly*, *Spider* and *Mantis* incorporate the *ARM7* risc processor core with a number of peripherals and support facilities on chip to give small, low-cost and low-power devices. Entry level to this range of livestock is the *Butterfly*, which has two uarts, a two-channel dma and a programmable interface, in addition to power management, flexible interfacing, timer/counters and programmable interrupt control. Spider also offers an on-chip V2.1 PCMCIA slave interface, a four-channel dma controller with programmable source and destination devices and a uart. Most extensive is the *Mantis*, which is *Spider*-like except that it has a 16bit peripheral interface and two uarts. There is a new software development toolkit and the first fully Windows-based debugger for the ARM processor, common to all three. Operating speeds are 15-30MHz, depending on type and voltage supply. GEC Plessey Semiconductors Ltd. Tel., 01793 518510; fax, 01793 518582.

Bright Sparc. When this appears, Sun is due to have its *UltraSPARC* risc processor available in quantity. The new 64-bit chip runs at 143MHz and 167MHz and has on-chip multimedia support. Its data throughput is 1.3Gbyte/s and the Visual instruction set allows it to run at 1.67Gop/s. Texas Instruments make the device, which is packaged in a 521-pin ball grid array. Sun Microsystems Ltd. Tel., 01276 451440; fax, 01276 451287.

3D graphics. Yamaha's *YGV612 (RPA2)* is a 3D graphics device that supports full texture mapping at 150Kpolygons/s for 3D, 50-pixel triangles and which will allow complete 3D accelerator boards to be sold for under £200. This is the second device in the *Virtuality* series and has dram frame buffer support, a glueless PCIbus interface and a 30MHz video d-to-a converter. It is compatible with Yamaha's earlier rendering polygon accelerator, the *YGV611*, and performs Gouraud shading, hidden surface removal, video capture and bit block transfer. Polar Electronics. Tel., 01525 377093; fax, 01525 378367.

Pentium for portables. Intel introduces the 90MHz *Pentium Processor Mobile Advantage*, intended for use in notebook and smaller computers, with a 3.3V interface to the outside world and 2.9V internal operation. Features include a package 'thinner than a dime', however thin that is, and an on-chip power-down circuit to rest the cache and floating-point unit when they are not needed. Intel Corporation UK Ltd. Tel., 01793 696000; fax, 01793 430763.

Oscillators

Controlled-crystal oscillators. M-tron's *MTET-1* is a ±1ppm oscillator responding to an external frequency control voltage. For an input of 0-5V, frequency varies by 5ppm in the frequency range 10-20MHz. Output is ttl/cmos-compatible and required power either 5V or 12V. Shielding by an all-metal welded case minimises radiation. Semi-Dice (UK) Ltd. Tel., 01494 714010; fax, 01494 712400.

Programmable logic arrays

MAX developments. Altera's *MAX 7000S* family of programmable logic devices is compatible in pinout and programming files with *MAX 7000/7000E* families, but now has in-system programming and JTAG boundary-scan testing. In-system programming eliminates the handling of devices during programming, since they can be board mounted in the normal way and programmed in *situ* with no risk of lead damage; the process of up-grading the design is also eased. Altera UK Ltd. Tel., 01628 488811; fax, 01628 890078.

Power semiconductors

Power mosfets. Power mosfets made by Ixys can now be specified in TO-247, which allows the devices to be surface-mounted to a pcb, having gull-wing leads and also the back of the package plated with lead/tin matte finish. Currently, there are three mosfets and four igbts with this option, denoted by an 'S' after the number. IXYS Corporation. Tel., (USA) 001 408 982 0700; fax, 001 408 496 0670.

PASSIVE

Communications equipment

Telephone chip. An fsk demodulator, the *Exar 2211*, is used by Nortel in a new telephone offering multistandard calling line identification. The *C9316* telephone has an lcd to guide the user through call logging, call duration timing and incoming caller's name and number. Using the Exar chip has allowed the identification process to be held in software, simplifying the telephone hardware and rendering it compatible with all known international standards. Nortel Europe. Tel., 0162 8812050.

Rf/microwave test set. Portable rf and microwave test sets by Marconi Instruments in the *6200B series* are developed from the *6200A* instruments and are meant for use by field engineers working on mobile and cellular radio antennas and associated links – a situation in which the ability of the *6200B MTS* to measure both return loss and real-time fault location to within 0.1% of the distance range is of particular value. New on these instruments is the *6240* fault locator which measures return loss and location from a single port. Features of the instrument include a scalar network analyser, a synthesised sweep generator, power meter and frequency counter. Frequency coverage of the five instruments in the series is 10MHz-40GHz. Up to 200 traces can be stored on a 3.5in dos-compatible disk for later import to a pc. Marconi Instruments Ltd. Tel., 01727 859292; fax, 01727 857481.

Connectors and cabling

Dimm sockets. Dual-in-line memory-module sockets from Robinson Nugent use a dual readout format to give an effective doubling of package density in a single-density area, a form used in workstations but not, until now, in pcs. Features include 60-cycle life, vertical entry, resistance to shock and vibration and a method of ejecting the modules. The 8byte socket has 168 positions and keying for 3.3V and 5V srams and drams. Robinson Nugent (Europe) Ltd. Tel., 01256 842626; fax, 01256 842673.

Displays

High-temp., high duty-ratio lcds. GEC-Marconi's Hirst-LCD has been able to combine a duty ratio of 1:240 with an 80°C operating temperature in new stn lcds to make them usable for military, automotive and outdoor use. These displays use the company's 270° twist technique to give high contrast and wide viewing angle. GEC-Marconi Materials Technology Ltd. Tel., 01327 350581; fax, 01327 353410.

Stn colour displays. Sanyo has a range of colour and monochrome supertwist nematic lcds, using chip-on-glass and chip-on-board techniques. *LMCF53/G53* are 11.4in and 14in vga colour modules, *LMFK53* is a 10.3in replacement with 800-by-600 resolution for pcs and *LMAE55* is a 9in vga monochrome type. All these dual-scan displays give high brightness and use a low-power backlight, the colour models having colour filters for better contrast and viewing angle. Anders Electronics plc. Tel., 0171 3887171; fax, 0171 3872951.

Pcb indicators. Three leds in one housing save board space and provide a more consistent alignment than separate leds. Dialight's *570 Series* uses three 2mm leds in red, green or yellow, and the 6.84mm distance from front to first lead conforms to DIN 41494. Viewing angle is ±19° and the units are in black epoxy to improve contrast.

Optical-fibre connector. Transradio announces the *FCPC monobloc*, a one-piece optical-fibre connector combining easy termination and a tuning optimisation facility. Connectors come fully assembled with the specified optical ferrule. Cable retention is provided by a standard crimp on the aramid yarn. Cable assemblies by Transradio's termination facility offer <50dB reflectance and <0.15dB insertion loss. Transradio Ltd. Tel., 0181 997 8880; fax, 0181 997 0116.

Dialight. Tel., 01638 662317; fax, 01638 560455.

SVGA lcd. Toshiba's *LTM10C035* is a liquid-crystal display to svga resolution of 800-by-600 pixels and measuring 10.4in diagonally. The active-matrix thin-film transistor technique gives a pixel size of 0.264 by 0.264mm and a response time of 50ms.An internal oxide layer and anti-glare surface improve contrast and cut reflection to 2% at a 550nm wavelength. A single fluorescent lamp takes only 3.5mA. Toshiba Electronics Europe Ltd. Tel., 001 49 211 52 96-392; fax, 001 49 211 52 96-400.

800 by 600 lcd. For its *P1000* series of 100MHz *Pentium* notebooks, Tadpole Technology has introduced the option of an active-matrix, thin-film transistor display supporting 800-by-600 graphics. The *P1000G*, for example, combines the 256-colour display, the *Pentium*, 256K second-level cache and 128Mbyte of memory, to run applications such as cad, modelling and multimedia, normally found on desk-top equipment. Tadpole Technology. Tel., 01223 428200; fax., 01223 428201.

Filters

Emc filter. Pcb-mounted mains filter by Belling Lee, the *SF3010*, is a compact device handling up to 250Vac at 1A, 2A or 6A and measuring 20-by-25 by 25mm. Operating frequency for all three filters is 0-400Hz. BLP Components Ltd. Tel., 01638 665161; fax, 01638 660718.

Hardware

Screened racks. *Barton*'s range of screened racks is extended to include a unit with a –70dB performance at 1GHz. It takes internal rack fittings from most rack component makers, meeting emc regulations comfortably. Largest is a 42-unit 19in model and there are standard fan tray mountings, ventilation, castors or adjustable feet and, as options, glass doors and a two-tone finish. Barton Engineering and Export Ltd. Tel., 01227 272141; fax, 01227 771653.

Instrumentation

Camera testing. *Optest VT-C1* from the Israeli company Genop is a modular, computer-controlled test station for the electronic and optical testing of camera systems, including monochrome and colour video, intensified ccds and slow-scan ccds, using a uniform light source and calibrated reticle in an enclosure. Computer control using the Windows-based software supplied provides automatic, integrated performance of a set of complex tests that usually require many separate instruments and do not give the documentation and analysis this system provides. Optilas Ltd. Tel., 01908 221123; fax, 01908 221110.

Semiconductor tester. Now in its fifth generation, Testronics's *201C Discrete Semiconductor Test System* is mainly intended for use in manufacturing. Depending on device type and test parameters, throughput is 3-10 times faster than in earlier instruments, a new 16bit data converter and a new Windows-based programming language being responsible for the speed increase. Instrumentation Test & Measurement Ltd. Tel., 01202 872771; fax, 01202 871052.

Interfaces

Avionics switching interface. DDL's *DD-01616* consists of 16 circuits switching lamp, solenoid or actuator loads when driven by the outputs of 8 or 16-bit microprocessors, primarily in avionics equipment; wire links configure the device for Intel or Motorola processors. Outputs drive at least two 40mA incandescent lamps and higher loads are possible by parallelling the switches; lamp life is extended by the controlled turn-on/off times. Short-circuit protection copes with inrush current but trips on working overcurrent, and comparators sense overcurrent or absence of current. Data Device Corporation. Tel., 01635 40158; fax, 01635 32264.

Network interface. A 16-bit Ethernet 10Base2/BNC adaptor card from MPS is for use with PC XT/AT computers and is Novell *NE2000* Ethernet adaptor-compatible. It has a BNC connector for the thin coaxial Ethernet interface and 15-pin D connector for AUI interface so that any Ethernet segment may be connected by means of an external transceiver. MPS Electronics. Tel., 01702 554171; fax, 01702 553935.

Literature

Allegro/Sanken. Allegro Microsystems Europe has a 16-page short catalogue listing Allegro and Sanken semiconductors. Allegro's mixed-signal devices and Sanken's power ICs and discrete components are all listed and categories include regulators and power management, leds, diodes, power devices, motor

Clamp-on induced current meter. *HI-3702 Clamp-on Induced Current Meter* by Holaday measures rf induced current in ankles and arms in the 3kHz-110MHz range at 1mA-1A, complying with ANSI C95 1-1992. To avoid perturbing the rf field, the readout and control unit is coupled by optical fibre and can be held in a belt case for hands-free use. It is intended for measurements in rf welding, induction heating, broadcast and aerial locations. Holaday Industries. Tel., 01628 478155; fax, 01628 476781.

Dual-measurement dmm. *Model 1705* from Thurlby Thandar is a bench digital multimeter that allows the measurement of two different signals simultaneously. There are both main and secondary displays: the latter is used to show the secondary range in addition to the measurement units; to display a measurement in two different units such volts and dBm; to display the result of a calculated function; measuring and displaying two aspects of one signal such as alternating and direct voltage; and measuring and displaying two different signals. Basically, the instrument is a 4.5-digit multimeter showing 10,000 counts and with a resolution of 10μV, 10mΩ and 0.1μA. Autoranging is used on most functions with manual selection if required. Response to ac is true rms and the attenuator is highly accurate in the audio band, giving wide-band response to prevent errors when measuring switching waveforms. Many calculated functions are provided and there is a 100-step data logger. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

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drivers and sensors. Allegro MicroSystems Inc. Tel., 01932 253355; fax, 01932 246622.

Automotive semiconductors. Toshiba offers a brochure on semiconductor devices for the automotive industry, including controllers, bipolar devices, Igbts and power modules, logic, diodes, leds and optical-fibre connectors. Toshiba Electronics UK Ltd. Tel., 01276 694600; fax, 01276 694800.

Switches. Switches by the *C&K Clayton/Unimax* division are described in a new catalogue from Roxburgh. In 220 pages, the publication covers additions to the range such as camlocks, switchlocks and rotary, rocker, pushbutton and slider types, most being approved and certified by the relevant authorities. A section on the possible combinations of features, 'Build-a switch', is included, complete with specifications, materials, drawings and ratings. Roxburgh Electronics Ltd. Tel., 01724 281770; fax, 01724 281650.

BLP. Crellon can let you have a 22-page catalogue of the offerings available from BLP Components, including Belling Lee filters, connectors and fuses; PED solenoids and relays; and Dialight optoelectronics products. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

Remote switching. Transmitter and receiver modules by Wood and Douglas allow up to ten different functions, such as lighting, irrigation, alarms, to be controlled over radio links of up to 15km. The *RTC450* 500mW transmitter has a four or ten function relay controller and is normally fitted with a quarter-wave antenna, with other types as options. Data receiver *RRC450* has the corresponding number of contacts rated at 1A at 240V ac. Both units are in Surtel-type enclosures, protected to IP65 standard. Supply is 12Vdc at 150mA. Wood and Douglas Ltd. Tel., 01734 811444; fax, 01734 811567.

Pcb repair. A manual on the repair and rework of printed-circuit boards by Circuit Repair Corp. is available from Intertronics. In more than 200 pages, it describes step-by-step procedures, base material and conductor repair and rework and plated-through hole repair. The work also comes on floppy disk in AmiPro and Word. Price for the manual is £44; for the disk, £444. Intertronics Ltd. Tel., 01865 842842; fax, 01865 842172.

Subminiature switches. Cherry has a brochure describing a range of small switches for low-power circuits, the *Type DB*. They conform to DIN 41636 sizes and come in normally open, normally closed or changeover form, versions handling 5A or 10A at 250Vac and 0.1A at 125Vac. Various actuators are available, including rollers, as are terminal types, and contacts are in silver/nickel or gold crosspoint. Cherry Electrical Products Ltd. Tel., 01582 763100; fax, 01582 768883.

Production equipment

Lead-forming tool. Fancort Industries offers the *F-1F/2FLEX* two-sided universal gull-wing lead former for surface-mounting flatpacks and quadpacks to any footprint, controlling the finished stand-off height to within ±0.002in. All dimensions, such as foot length, shoulder length and radii are adjustable and the tool fits the Fancort *5000-1* floating anvil press which uses an electronic system to maintain stand-off height. The tool handles both sides of a component simultaneously and, as an option, there is a loader. Production Equipent Sales Ltd. Tel., 01323 811694; fax, 01323 811528.

Power supplies

Power trays. *PT series* 19-in power trays by XP are improved and extended. They provide completely packaged power for all XP supplies and dc-to-dc converters in heights from 1U in 360 or 500mm depths. Many combinations of ac and/or dc input can be accommodated, depending on the selection of psu or converters and many combinations of output to customer requirements. XP plc. Tel., 01734 845515; fax, 01734 843423.

3V regulators. Allegro's *A818x* series of low drop-out voltage regulators now contains devices with a fixed 3V output giving up to 150mA at an input/output differential of under 150mV. Current used in the device itself is 65µA normally, 1µA when sleeping. Rated input is 0-10V, over which range stabilisation is within 30mV. Thermal protection is provided and there is a ttl-compatible enable input. Flint Distribution. Tel., 01530 510333; fax, 01530 510275.

OS9-to-pc link. Version 3 of BVM's *Pclink* enables full two-way transparent network access with on-the-fly conversion and resource sharing between OS-9 real-time machines and pcs running under dos or windows. A main advantage is that OS-9 developers can make use of the well established text editors and compilers available for windows. One new feature is OS-9 access to network file servers by linking into a client pc then communicating transparently with the server using normal pc networking software. Print spooling is also supported. BVM, Tel., 01489 783589, fax, 01489 780144.

SM dc-to-dc converters. Calex has a range of surface-mounted dc-to-dc converters handling up to 15W. *SD* single-output series of units gives 5V and 3.3V output from inputs of 6.5-15.5V dc and 4.5-6V dc. Output noise is under 40mVpk-pk, Stabilisation 1.7% and regulation 0.2%. The units occupy 2-by-0.75in, and are 0.5in high. Calex Electronics Ltd. Tel., 01525 373178; fax, 01525 851319.

Switches and relays

Current trip amplifier. Foxtam Controls offers the *11WRI/T* 1-20mA trip amplifier, which provides trip current monitoring with or without latching. It is in a plug-in housing, which also carries separate trip-level and hysteresis controls, relay status indication and adjustable start-up inhibit delay timer. Models to suit a range of ac supplies are available. Foxtam Controls Ltd. Tel., 0161 626 5316; fax, 0161 627 0929.

Transducers and sensors

Shaft encoder. Low-cost shaft encoders from Control Transducers, the *DP* series are easy to install devices for use as feedback and positioning controls in industrial machinery. The 16 models in the series are non-contacting, optical types with resolutions from 96 to 2048 lines per revolution. Diameter is from 1in, mounting is by a single hole and the units are of low torque design, coping with continuous speeds of up to 10,000rev/min. Optional accessories include a line driver, cables, a variable power supply and various ICs. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

Thermal imaging. Vero's *Thermochromic Heat Imaging* board provides a hardware method of determining a system's thermal characteristics, rather than software modelling. Boards coated with thermal ink are placed in a slot or near the object of interest, different colours appearing at various temperatures, a detectable change in colour occurring every 1°C. Eurocard, Futurebus and a universal size are available and there is a transparent front panel in popular sizes to allow the realistic airflow while the boards are examined. Electrospeed. Tel., 01703 644555; fax, 01703 610282.

Tilt sensor. Using the force-balance principle, the *ES-256 Series* of inclinometers from Control Transducers is both extremely accurate and resistant to hostile conditions. Linear output of ±5V over full-scale ranges from ±5.75° to ±90°needs a single 10.5-28V supply, non-linearity being ±0.05%, repeatability ±0.005%, resolution 0.001% and operating temperature –40°C to 85°C. A stainless steel case protects the instruments and there is a variety of damping, insulation and connection options. Control Transducers. Tel., 01234 217704; fax, 01234 217083.

Data communications

PCI data highway. Myriad Solutions announces the *Q-Card*, which uses the National Semiconductor *QuickRing* data streaming controller to provide a peak data rate between nodes of 200Mbyte/s and will receive and transmit data at the PCIbus limiting bandwidth of 132Mbyte/s as either PCI master or slave. Cards plug into any PCI-based computer and give a means of linking computers to other computers and peripherals. Software to allow the cards to be incorporated into applications is provided. Myriad Solutions. Tel., 01223 421181; fax, 01223 421228.

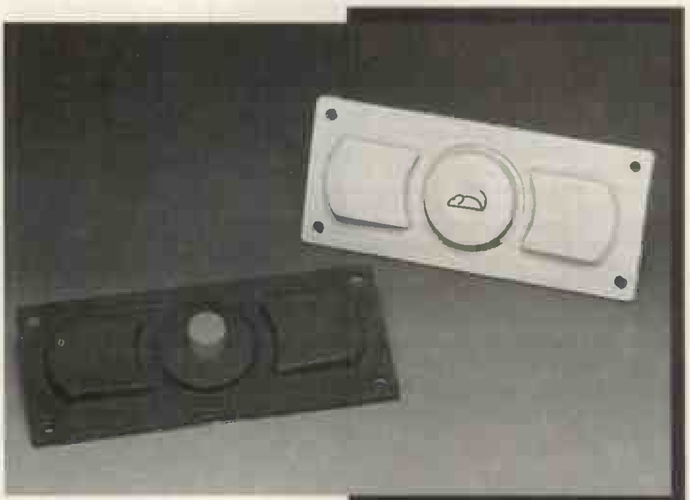
Power-line transformers. Transformers by Etal in the *P28xx* range have been designed for use in the linking of equipment that uses the mains wiring to carry high-frequency signals. Transformers for this duty have not commonly been made to close tolerance, with the result that the electronics has had to cope expensively with the variations. These transformers are more closely controlled and cover four bands between 40kHz and 148.5kHz, each conforming to EN60950 and EN50065-1. Etal Electronic Techniques Ltd. Tel., 01473 611422; fax, 01473 611919.

COMPUTER

Software

Data acquisition. Additions to Amplicon's *LABTech Notebook* to make version 8 are operation under windows, FFT analysis of real and complex waveforms, real-time vision gui and sound support and interfacing to spreadsheets by dde or streaming to hard disk at up to 1MHz. Flexibility in the software is preserved from earlier versions and remote control over networks is a feature: for example, Notebook can be run on one machine and be controlled and have its output monitored on another. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

Dsp development. *DSP Blockset* by Cambridge Controls is claimed to be the first to combine dsp algorithm development with real time prototyping and implementation. It is an extension of the *Simulink* non-linear simulator and is used with the *Matlab* environment. There is a library of over 100 basic dsp operations and the software converts point-by-point data samples to data vectors. An optional feature converts block diagrams to portable, ANSI C code to run on any programmable floating-point dsp equipment. The package runs on 486 pcs under windows, on Mac *68000* and *Power Macs* and on most Unix workstations. Cambridge Control Ltd. Tel., 01223 423200; fax, 01223 423255.



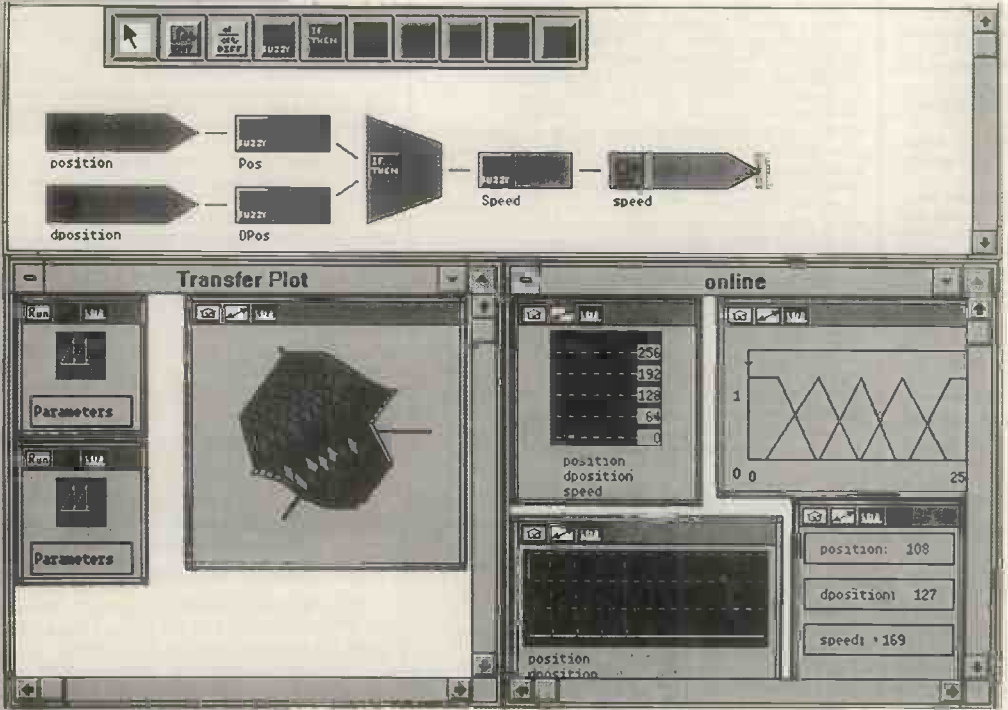
Sealable mouse. With a mounting depth of only 6mm, Interlink's *MicroModule* mice are sealable and suitable for industrial applications and heavily used commercial environments such as information kiosks. There are two options, one providing button cursor pointing control, the other with a mini joystick. Both versions offer two-button click control. Interlink Electronics, Tel.,805 484 8855, fax, 805 484 8989.

Telecoms simulator. *Saber Telecommunications Simulation Package* combines a library of telecoms building blocks with the latest version 3.4 of the Saber mixed-signal simulator to form a design and analysis tool for people working on analogue and digital cellular and landline systems. Component models and templates are programmable in MAST, Saber's own language, and can be enhanced or used as a starting point for a user's own model, models in C, Fortran and Spice also being usable. For analysis, Saber tst now includes features such as Smith and Nichols chart display and eye diagrams to show digital signal degradation. Analogy Europe. Tel., 01793 432286; fax, 01793 488098.

EMI analysis. Version 2.0 of *Quiet*, the electromagnetic interference analysis tool by Quad Design, is now available. Predicting electric and magnetic field intensities from boards, the package now includes a 3-D simulation engine to provide better simulation of, for example, common-mode current and radiation in cables. Further, since the use of multiple boards distorts the predicted performance of a single one, a new facility predicts the effects of shielding and scattering for the whole structure. The package also handles enclosure resonance. Quad Design. Tel., 01344 306166; fax, 01344 304747.

Notepads. As a replacement for sticky bits of yellow paper, ScreenMagic offers *Stick-ups*, which is a note-taking and keeping facility for windows. It has a great number of clever features, one of which is voice entry, assuming you have bought the sound card and microphone. Drag-and-drop is operative, so that notes can be attached to other documents, and an instant save feature avoids the need to type file names. Additionally, alarms will wake you up at meeting time or provide 'continuous animated reminders'. Guildsoft Ltd. Tel., 01752 895100; fax, 01752 894833. ■

Fuzzy toolkit *HI-FLAG* is a development toolkit for fuzzy logic from the Swiss company Hiware AG. Design, simulation and debugging elements of the development have a graphic user interface and fuzzy objects – the variables and inference objects – are freely movable in the screen design area, properties being edited by double-clicking and groups of objects being placed in different debugging windows to make create methods. The simulator allows any input function to be mapped into the system and simulated and complex fuzzy systems can be designed by integrating non-fuzzy functions into the fuzzy design. Output is C or optimised assembler code for the target processor – for the *68HC16* now and then for all Motorola mcu series of embedded controllers. Pentica Systems Ltd. Tel., 01734 792101; fax, 01734 774081.



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WIRELESS VIDEO BUG KIT Transmits video and audio signals from a minature CCTV camera (included) to any standard television! All the components including a PP3 battery will fit into a cigarette packet with the lens requiring a hole about 3mm diameter. Supplied with telescopic aerial but a piece of wire about 4" long will still give a range of up to 100 metres. A single PP3 will probably give less than 1 hours operating time. £99 REF EP79. (probably not licensable!)

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PC PAL VGA TO TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware.. Ideal for laptops or a cheap upgrade.Supplied in kit form for home assembly. **SALE PRICE £25 REF SA34**

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AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. **SALE PRICE £8.99 REF SA25.**

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PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

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13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3

PPC MODEM CARDS. These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 **REF: MAG5P1**

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COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance. Complete kit £8.99.

ELECTRIC MOTOR KIT Comprehensive educational kit includes all you need to build an electric motor. £9.99 ref MAR10P4.

VIEWDATA SYSTEMS made by Phillips, complete with internal 1200/75 modem, keyboard, psu etc RGB and composite outputs, menu driven, autodialler etc. **SALE PRICE £12.99 REF SA18**

AIR RIFLES .22 As used by the Chinese army for training puposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80.

PLUG IN POWER SUPPLY SALE FROM £1.50 Plugs in to 13A socket with output lead. three types available. 9vdc 150mA £1.50 ref SA19, 9vdc 200mA £2.00 ref SA20, 6.5vdc 500mA £2 ref SA21.

VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 **REF: MAG15** 12v psu is £5 extra **REF: MAG5P2**

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***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER COMPLETE WITH COINSLOT MECHANISMS originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? **SALE PRICE JUST £2.50 REF SA23**

GAT AIR PISTOL PACK Complete with pistol, darts and pellets £12.95 Ref EF82 extra pellets (500) £4.50 ref EF80.

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. **SALE PRICE £4.99 REF SA24.**

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WANTED: TUBE for Solartron CD1400 oscilloscope, type SE5/2A. Poole 01202 602722.

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WANTED: pre-war television. Jac Janssen, Hogeham 117D, NL-5104JD Dongen, Netherlands. Tel: 01031 1623 18158. Fax (office): 01031 13 624664. Thanks!

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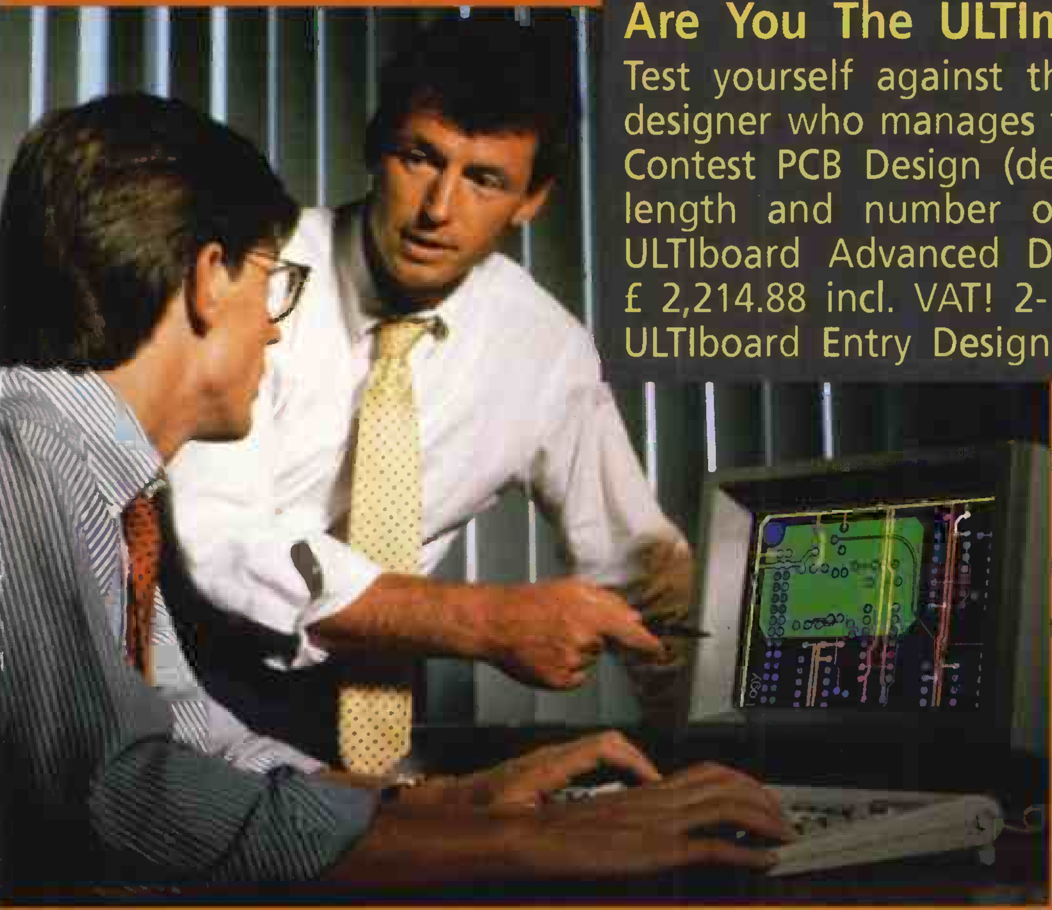
Are You The ULTImate PCB Designer?

Test yourself against the best in the UK! The designer who manages to make the best quality Contest PCB Design (determined by total trace length and number of vias) will receive an ULTIboard Advanced Designer, valued at over £ 2,214.88 incl. VAT! 2-10 prize winners win an ULTIboard Entry Designer valued at £ 1,521.63.



Competition Entries will be judged by an independent jury, consisting of experts in the field of electronic design and production. So that we can judge your design, contenders need to provide us with:

- **an ULTIboard ddf file or**
- **a Gerber (photoplot) file of any PCB Design System plus printouts that clearly show trace widths, pad sizes number of vias and total trace length.**

The contest closes on 1st Nov, 1995. The 10 Winners will be personally informed, and the results published. No correspondance will be entered into and the judges decision is final!

The contest design may be perfectly designed with the ULTIboard Challenger Lite a 32 bit Schematic Entry and PCB Layout Tool with a design capacity of 500 pins. This Version includes an internal gridless autorouter, that routes by nets, component or block.
Minimum Hardware requirements are: 80386 (SX), 2 Mb RAM and Colour VGA. No Purchase is required to enter the competition and all employees & distributers of ULTImate Technology are excluded. For those who wish to purchase their own PCB Design System the 32 bit Challenger Lite is available on special offer for a limited period only.

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ENTRY FORM Please fax of send back this form (one design per entrant only) to **ULTImate Technology (UK) Ltd**, 2 Bacchus House, Calleva Park, Aldermaston, Berkshire RG7 4QW England, Fax: 01734 815323

Name : ____________________

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Please send me a competition pack including: Net List on floppy disk and paper and design rules (minimum trace widths & clearances, pad and via sizes) etc.

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